White Paper

Southern New Castle County Wastewater Plan

(Draft Sep 20, 2017, revised Oct 25, 2017, Aug 20, 2018, Feb 8, 2019, and Apr 29, 2019)

Prepared for:

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1. Background

Septic systems work by utilizing the dilution qualities of rain water to convert urea and organic nitrogen in human waste to ammonia and ammonium for discharge to groundwater (Figure 1). Septic systems usually last for about 20 years and can properly treat wastewater in rural areas provided these systems are situated on large lots (>2 acres) with permeable soils (>1 in/hr) and deep water table (> 10 ft) and are pumped out every 2 to 3 years by property owners. When septic systems are not installed and operated in accordance with these criteria, these systems can discharge high amounts of nitrogen (>10 mg/l) and contribute to surface and ground water pollution.

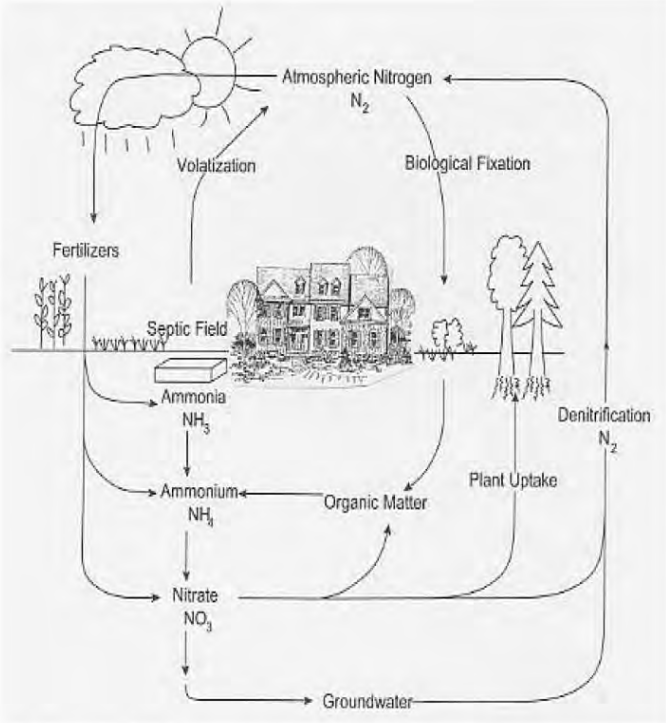


Figure 1. Nitrogen cycle (adapted from Alliance for the Chesapeake Bay fact sheet)

Figure 1. Nitrogen cycle from Alliance for the Chesapeake Bay fact sheet.

The University of Delaware Water Resources Center (UDWRC) was requested by the New Castle County Department of Land Use to draft a white paper that utilizes our GIS lab to map and collect data on septic system use in New Castle County focusing on the area south of the C & D Canal. We utilized data collected from DNREC and data collected in our GIS lab from the following reports: (a) South New Castle County Priority Watershed Strategy (2006), (b) 9th Report to Governor and General Assembly regarding the Progress of the Delaware Water Supply Coordinating Council, Estimates of Water Supply and Demand in Southern New Castle County through 2030 (2006), and (c) Wastewater Needs Evaluation and Plan for Southern New Castle County by Roy F. Weston, Inc (1992).

A review of our GIS data base indicates about 3,500 active septic systems and 800 inactive septic system permits are situated in the East, Middle, and West Wings of southern New Castle County between MOT and the C & D Canal (Figure 2). We recommend that upcoming amendments to the New Castle County Comprehensive Plan to map the boundaries of the sewer service area and include specific provisions for a septic system relief program to connect sewer to aging neighborhoods (over 25 years old) in the growth area between MOT and the C &D Canal in southern New Castle County. Figure 3 delineates the boundaries of the New Castle County sewer service area.

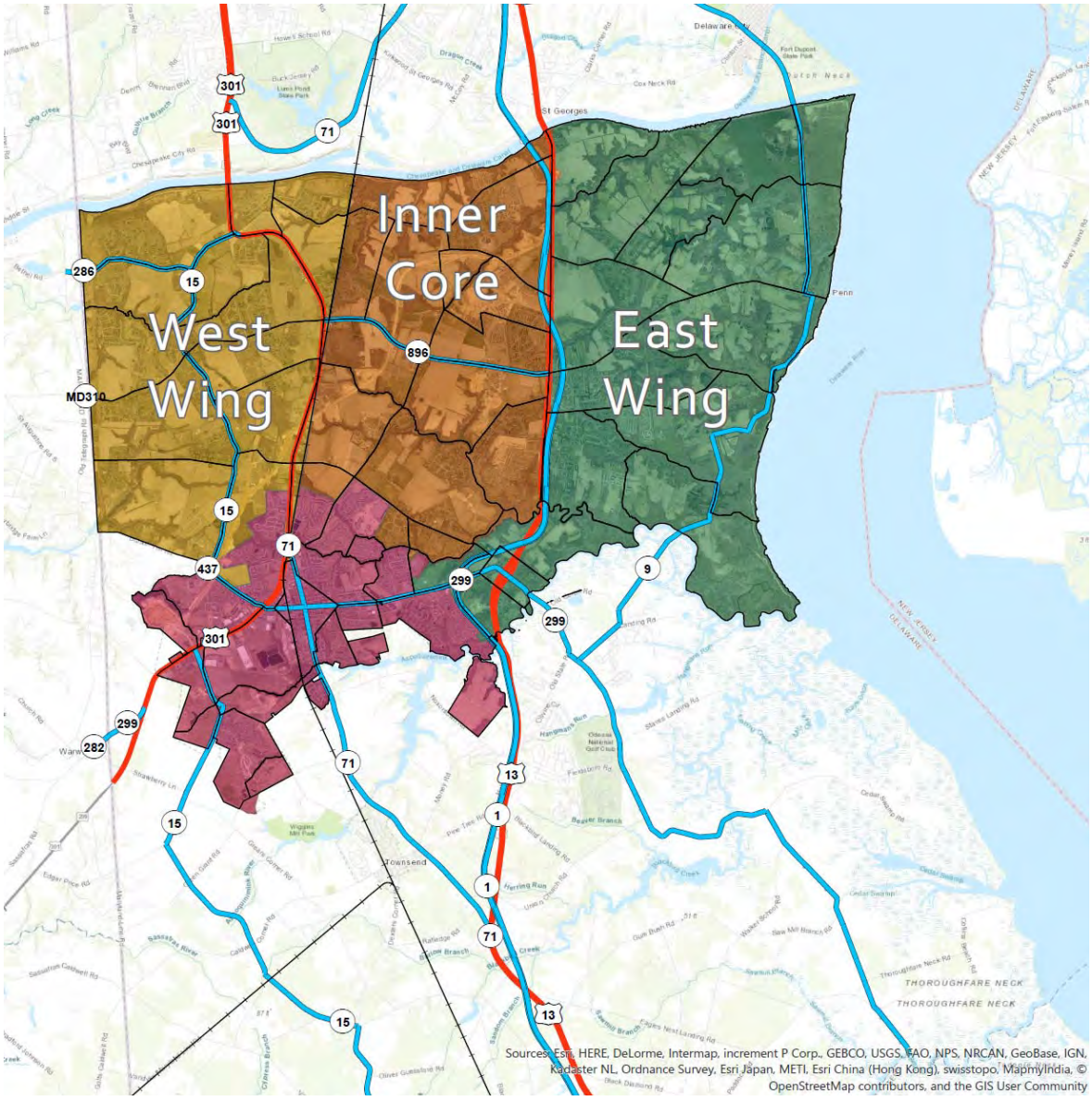


Figure 2. West Wing, Inner Core, and East Wing planning areas of southern New Castle County

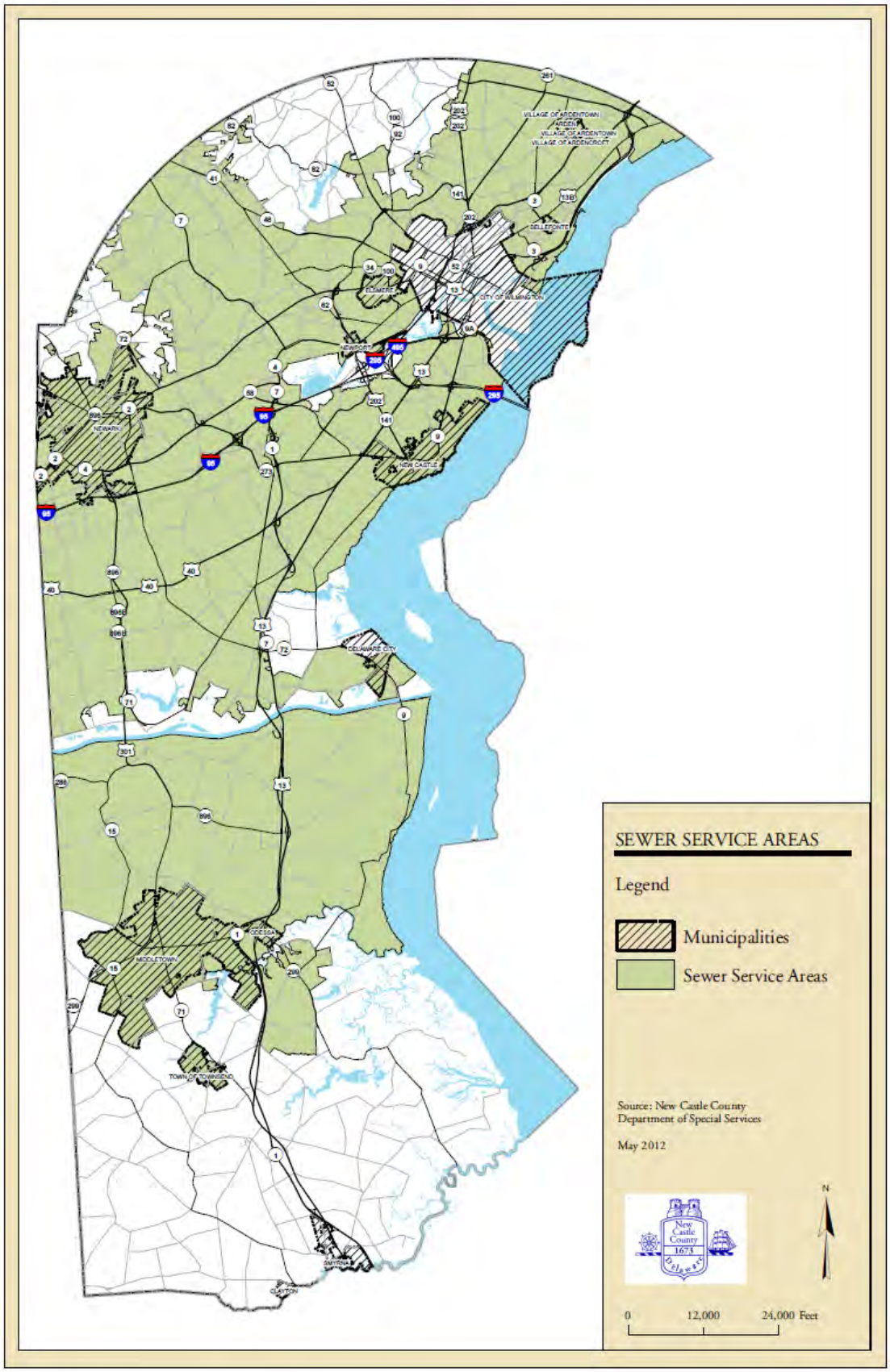


Figure 3. New Castle County sewer service area

2. Scope of Work

The UDWRC conducted this work in accordance with the following tasks:

1. Prepare a white paper that summarizes septic system use in New Castle County south of the C&D Canal.

2. Evaluate the 2012 New Castle County Comprehensive Plan to determine if the plan adequately addresses use of privately owned septic systems in large residential subdivisions.

3. Review the central New Castle County wastewater service area and areas west and east of the sewer area where low density development is concentrated to evaluate the intensity of septic systems use there as the primary means of sanitary waste disposal.

4. Utilize our GIS to map and assemble a database with the follow layers:
   - Number of houses which use septic and private wells in the West and East wings.
   - Number of houses which use septic and public water systems in West and East wings.
   - Number of houses being planned to use septic, private wells, and public water systems.
   - Map septic systems with depth to groundwater, age of system, and proximity to streams.
   - Projected built out scenario for entire area south of canal.
   - Should residential lots be a minimum size to account for drainage fields in case one septic drainage field fails and the homeowner requires another one.

5. Research septic systems codes and regulations in other counties on the Delmarva Peninsula.

6. Estimate costs and pollutant loads from septic systems compared homes in public sewer areas.

7. Provide recommendations to update the 2012 Comprehensive Plan, create policies to limit septic systems location, increase septic lot size due to failed drainage fields, soil/groundwater limitations.

3. Demographics

Land Use: Southern New Castle County, Delaware is a rapidly suburbanizing 200-square mile region south of the Chesapeake and Delaware Canal that includes the towns of Middletown, Odessa, and Townsend (MOT). By 2012, land use was covered by 43% agriculture, 37% forest, wetland, or open space, and 20% was urban/suburban (Table 1 and Figure 4). The New Castle County Department of Planning estimates up to 20,000 dwelling units, with a mean gross density of one unit per acre, may replace 20,000 acres (31 square miles) of agricultural land, thus doubling the area of urban/suburban land by 2030. Forests, wetlands, and public open space are expected to remain constant as these areas are protected by Federal, State, County, and municipal regulations.

Table 1. Land use in southern New Castle County (2002, 2012, and 2030)

Land Use	2002 Area (sq. mi.)	2012 Area (sq. mi.)	2030 Area (sq. mi.)	2002 Area (%)	2012 (%)	2030 Area (%)
Urban/Suburban	30	40	61	15%	20%	31%
Agriculture	96	85	65	48%	43%	32%
Forest/Wetlands/Open	74	74	74	37%	37%	37%
Total	**200**	**200**	**200**	**100%**	**100%**	**100%**

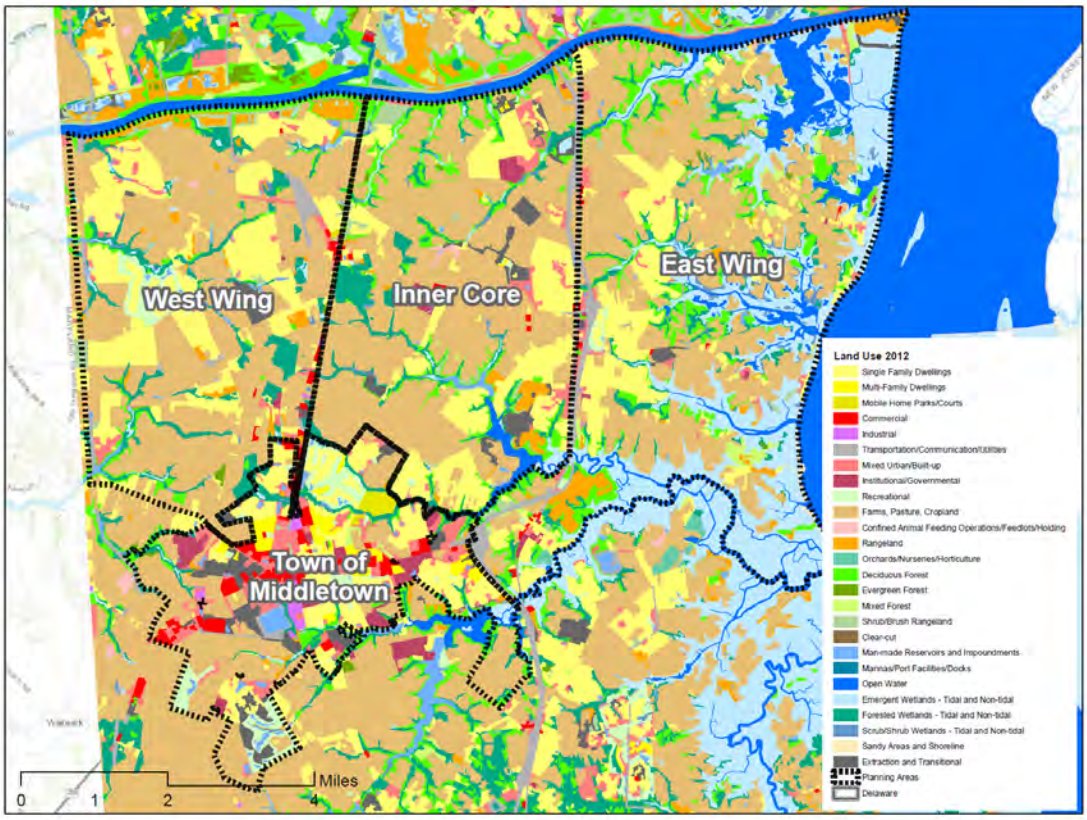
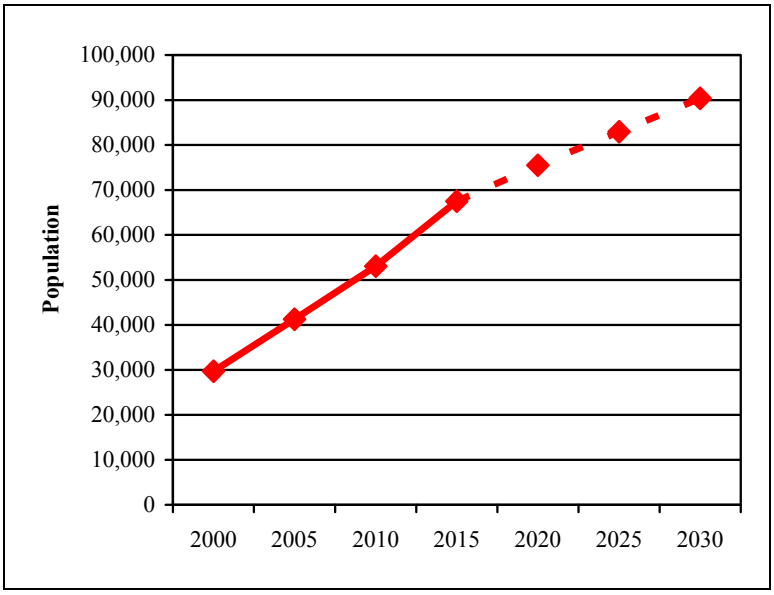


Figure 4. Land use in southern New Castle County, 2012

Population: Population growth and the conversion of agricultural land to urban and suburban uses is expected to continue to increase the demand for wastewater management services in southern New Castle County. The Delaware Population Consortium (2016) projected that the population in southern New Castle County, Delaware (south of the C&D Canal) will increase from 67,499 in 2015 to 90,376 by 2030 or by 11.8% from 2015 to 2020 and another 19.7% from 2020 to 2030. (Table 2 and Figure 5).



Source: Delaware Population Consortium, November 2016

Figure 5. Projected population growth in southern New Castle County

Table 2. Projected population in New Castle County through 2030
(Delaware Population Consortium 2016)

Year	NCC Population		No. NCC Population		So. NCC Population	
	#	%	#	%	#	%
2015	556,786	---	489,499	---	67,499	---
2020	572,820	2.8%	497,331	1.6%	75,489	11.8%
2030	595,664	4.0%	505,288	1.6%	90,376	19.7%

4. Septic System Codes and Regulations

New Castle County: In 1997, New Castle County adopted the Unified Development Code (UDC) that set standards for individual septic systems that specified minimum lot size requirements for unsewered lots (1 acre for unsewered lots served by private wells and ¾ of an acre for unsewered lots served by public or community water supply systems). Several years ago, New Castle County Code Chapter 40 (Unified Development Code or "UDC"), Article 22 ("Drainage, Utilities, Septic Systems, Parking, Loading, and Lighting") was amended to remove minimum lot size requirements for unsewered lots (1 acre served by private wells and ¾ acre served by public or community water supply systems). The revised code specifies that DNREC regulations govern the septic system approval process in New Castle County subject to local conditions including ½ lot minimum which is the statewide standard.

The New Castle County Unified Development Code specifies these requirements for septic systems: Septic systems may be utilized subject to the applicable regulations of DNREC.

Sec. 40.22.330. - Use of on-site wastewater disposal (septic) systems

Where discharge to a sanitary sewer system is not required in accordance with Section 40.22.320 in the County shall be systems that have been approved by DNREC.

Sec. 40.22.320. - Wastewater disposal connections.

All lots that discharge sanitary sewage shall be permanently connected to a wastewater disposal system designed and constructed to comply with all applicable County and Delaware Department of Natural Resources and Environmental Control ("DNREC") regulations. No wastewater disposal system shall be installed upon any lot or parcel of land unless permitted by this Code. A connection fee, as determined by the Department of Public Works, shall be charged to any lot owner who is required by this Article to connect to the County sewer system unless an impact fee was incurred pursuant to Article 14.

Delaware: Delaware DNREC regulations governing the design, installation, and operation of on-site wastewater treatment systems specify that:

5.1.1. For residential dwellings, the maximum siting density shall be one (1) dwelling unit per one half (1/2) acre.

5.2.1.3.1 Percolation rates, actual or estimated, > 120 minutes per inch (0.5 in/hr) are very slowly permeable and constitute a limiting layer. Such sites shall not be suitable for new construction.

5.3.2.1 Percolation rates < 20 minutes per inch (mpi) (3 in/hr) will not be allowed for designing any on-site wastewater treatment and disposal system, unless otherwise approved by the Department.

Delaware DNREC regulations require 1/2 acre minimum lots (Table 3). New Castle County formerly specified 1-acre lots for septic systems with individual wells and ¾ acre lots connected to public water supply. Kent County allows septic systems in 1, 2, 3, and 4 acre lots depending on the zoning classification. Sussex County allows septic systems on ½ acre lots with public water and ¾ acre lots with individual wells. The State of Maryland requires 20,000 sq. ft/lot with septic systems.

Table 3. Minimum lot sizes for septic systems

County/State	Min. Lot Size w/ Well (ac)	Min. Lot Size w/ Public Water (ac)
State of Delaware	1/2	
New Castle County (formerly)	1	3/4
Kent County	1, 2, 3, 4	
Sussex County	3/4	1/2
State of Maryland	1/2	

NCC Comprehensive Plan: The New Castle County Comprehensive Development Plan (2012) discusses water and sewer planning in Chapter 5.2 (Sanitary Sewer) as follows.

North of the Chesapeake Delaware (C&D) Canal, the majority of the generated sewage within the Sewer Service Area is conveyed through a network of sanitary sewer pipes and pump stations via nine major interceptor lines to the Wilmington Wastewater Treatment Plant. South of the C&D Canal, the Sewer Service Area is comprised of five areas, one of which is not presently served by an existing sewer infrastructure. The other four have sewer treatment and disposal facilities; one privately owned, one in the Town of Middletown and two controlled by New Castle County. In lieu of public sanitary sewer, private sewage facilities must be reviewed and approved. In areas where existing private septic systems exist in proximity to the public sewer system, a community septic elimination program is in place to assist with conversion from private to public sewer. The average cost is $25,000 per property.

1. Continue to provide capacity in sewer service areas to meet demands for existing and additional development.

2. Continue to improve the efficiency of the administration and operation of the sanitary sewer system in order to minimize the expense to sewer customers.

3. Continually maintain and upgrade the existing sanitary sewer conveyance system of pipes, manholes, pump stations and wastewater treatment facilities to help ensure trouble-free operation.

4. Continue to improve the efficiency of the existing sewer system by increasing capacity through the reduction of infiltration and inflow of stormwater and illicit discharges into the sewer network.

5. Continue to explore new technologies and techniques of wastewater treatment, disposal, and re-use.

6. Implement a system maintenance funding strategy that protects the County's facilities investment by implementing a routine infrastructure replacement program.

7. Continue to expand the County's Septic Elimination Program" in order to assist communities with high percentages of failing septic systems to connect to the public sewer system.

Wherever financially and physically possible, the County accepts communities petitions to have the County facilitate a septic elimination project relieving homeowners of their problematic septic systems and eliminating adverse environmental impacts of failing septic systems. There are thousands of households in New Castle County currently on septic systems and conversion of all to sewers would be prohibitively expensive. As funding permits, the County seeks to conduct septic elimination projects that prioritize communities with failing systems with potential negative environmental impacts. If 70% of the residents within a subdivision desire to convert from utilizing their existing septic systems in favor of connection to the public sewer infrastructure, typically due to numerous septic failures, the County may consider undertaking a septic elimination program.

8. Provide sewer capacity that may facilitate infill development within existing developed areas and the redevelopment of brownfields, abandoned and underutilized properties.

9. Continue efforts to establish a definitive strategy and policy for the provision of sanitary sewerage within the "Southern Sewer Service Areas" south of the C & D Canal.

The provision of public sewerage serving subdivisions and land development proposals within the New Community Development Area shall be given highest priority for authorization to connect to a public sewer system. It is the objective of the County to facilitate provision of public sewerage to properties within the New Community Development Area (currently without sewer facilities) with conveyance of sewage to treatment/disposal facilities in Middletown and Water Farm #1 as a short term plan. Figure 6 depicts the New Community Development Area in southern New Castle County.

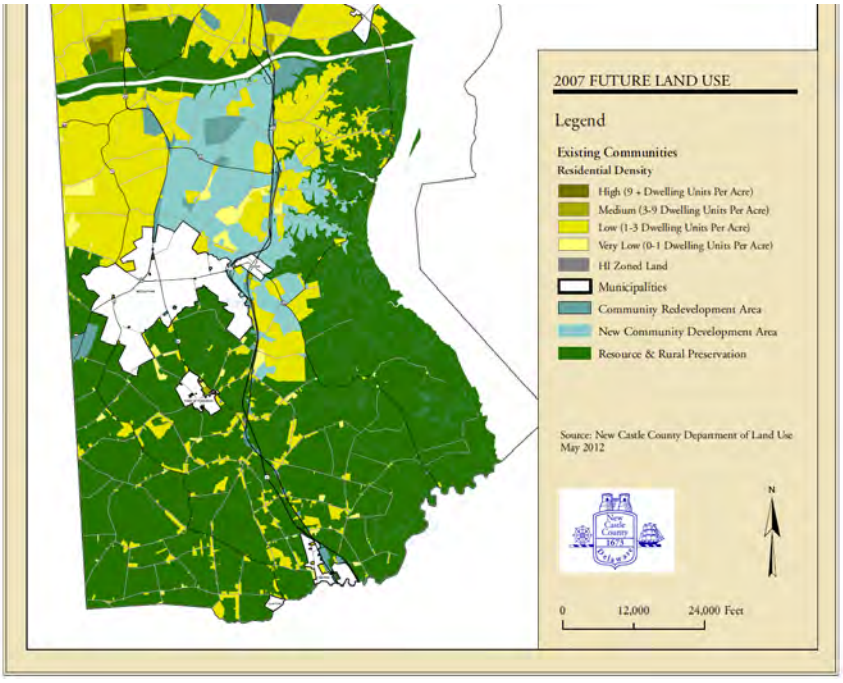


Figure 6. Future land use in New Castle County that includes a New Community Development Area.

Chesapeake Bay Watershed: The State of Delaware Chesapeake Bay Watershed Implementation Plan (2010) established maximum nitrogen load allocations from septic systems (Figure 7) of 28,000 lb/yr or 20% of the 140,000 lb/year load in the Elk River, C&D Canal, Bohemia River, and Sassafras River watersheds in southern New Castle County (Table 4). Nitrogen load allocations from septic systems in the Chesapeake Bay watershed in Delaware are 262,663 lb/year or 11% of the total 2,993,504 load to the Bay. The Chesapeake Bay WIP in Maryland concluded that new homes on septic systems generate 5 times more of the load than homes in sewer areas.

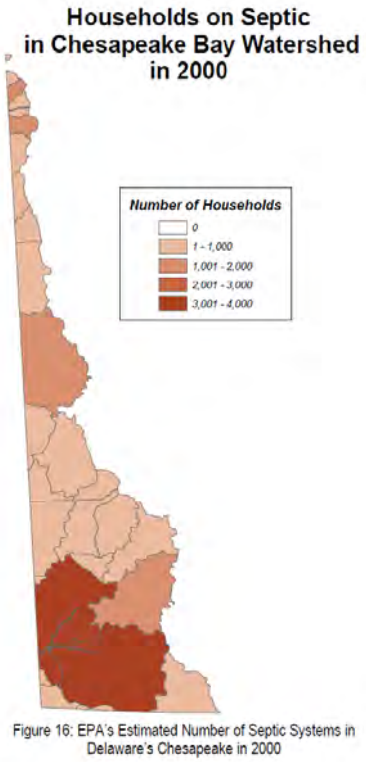


Figure 7. EPA estimate of septic systems in Delaware portion of Chesapeake Bay watershed

Table 4. Nitrogen load allocations (lb/yr) in Chesapeake Bay watershed in Delaware (Delaware Chesapeake Bay Interagency Workgroup 2010)

CB303(d) Seg.	Agriculture	Unregulated Stormwater	Septic	Forest	Nontidal Water Deposition	Subtotal
ELKOH	512		4,772	2,109		7,393
C&DOH-MD	24,417		14,100	5,375	195	44,087
C&DOH_DE	11,189		1,828	3,073	705	16,795
BOHOH	29,916		4,883	3,976	150	38,925
SASOH	24,778		2,380	5,066	9	32,233
CHSTF	86,161		13,555	23,202	190	123,108
CHOTF	205,733		25,160	42,516	460	273,870
NANOH	275,038		20,185	57,488	408	353,120
NANTF_DE	1,559,277		170,841	250,225	16,775	1,997,119
NANTF_MD	7		26	54		87
POCTF	80,484		3,845	18,003	17	102,348
WICMH	2,234		1,086	1,097		4,417
Subtotal	2,299,747		262,663	412,184	18,910	2,993,504

According to the State of Delaware Chesapeake Bay Watershed Implementation Plan (2010), the New Castle County portion of the bay watershed includes the Elk River, C&D Canal, Bohemia River, Sassafras River, and Upper Chester River. These watersheds have experienced residential growth where Middletown and surrounding environs have increased population by 100% from 2000 to 2008 without significant investment in sewer. The Town and County have set goals to offer regional wastewater treatment to 9,615 parcels in these watersheds by 2025 (Table 5) and minimize septic systems by limiting to 1 unit per 5 acres or 1 unit per 10 acres.

Table 5. Residential wastewater type for New Castle County in the Chesapeake Bay watershed (State of Delaware Chesapeake Bay Watershed Implementation Plan 2010)

EPA River Segment	2010 Land Use Scenario		2017 Land Use Scenario		2025 Land Use Scenario	
	Septic	Sewer	Septic	Sewer	Septic	Sewer
2981	23			33		43
2983	548		397	639		1,354
3010	1,618		1,604	897		3,375
3011	1,062		1,062	772		2,126
3201	267	319		1,194		1,830
3361	89			354		586
3520	106		106			301
Total	**3,713**	**319**	**3,169**	**3,889**		**9,615**

Maryland: According to the State of Maryland Department of Planning:

- Septic systems cause 10 times more pollution to Chesapeake Bay compared to public sewer.
- Septic development consumes 8 times more land per lot than homes in public sewer areas.

The 2012 Maryland Septic Act is expected to produce the following statewide benefits over 25 years:

- Reduce 50,000 new septic systems
- Prevent the loss of about 100,000 acres of forest and farmland
- Large-lot development on septic (2 ac/lot on average)
- Reduce about 1 million pounds of nitrogen from entering local streams and Chesapeake Bay

In Maryland in 2009, homes on septic systems cost $50,000 more than homes on sewer. The 3,500 septic systems in southern New Castle County discharge 81,200 lb of nitrogen to the environment or 10 times more than homes on public sewer. According to the Chesapeake Bay model, a person served by a conventional septic system discharges 8.82 lb of nitrogen to groundwater or an average home with 2.63 persons discharges 23.2 lb. of wastewater to the environment (Table 6).

Table 6. Direct Costs: Sewer vs. Septic

Direct Costs: Sewer vs. Septic	Household on Sewer	Household on Septic
Initial Hookup/Installation	$500 to $7,500	$6,000 (conventional)
Annual Fee/Maintenance Cost	$200 to $800	$65 (conventional) to $365 (BAT)
Offset Costs for New Wastewater and Urban Stormwater Loads	2.51 lb N/yr	22.82 lb N/yr
Cost Per Pound of Nitrogen Removal	ENR upgrade - $295/lb N.	BAT Upgrade - $12,000, removes 15 lb of nitrogen per year, $800/lb N.
Septic System Retrofit Hookup to WWTP	n/a	$15,000 - $35,000 MDE

5. Wastewater Needs

2006: The 2006 Southern Sewer Area Wastewater Program Evaluation for southern New Castle County provides population and wastewater flow estimates for the area south of the C&D Canal (Red Oak Consulting, 2006). The plan estimates peak wastewater flow of 4.5 mgd in 2006 and 12.1 mgd by 2030 (Table 7). This projection assumes an additional 25,244 dwelling units will be constructed in southern New Castle County at 1.0 du/ac. Wastewater flow is approximately 90 percent of water demand. Spray irrigation is a wastewater treatment technique where water is reused and recharged into the aquifer. The supply estimates in this report are conservative as they do not include aquifer recharge from spray irrigation systems in southern New Castle County.

Table 7. Summary of wastewater flow in southern New Castle County.

Sector	Wastewater Flow: Initial 2006 (mgd)	Wastewater Flow: Buildout 2030 (mgd)
Residential	--	9.2
Employer	--	1.1
Process	--	0.7
TOTAL	**4.5 mgd**	**12.1 mgd**

1992: In Roy F. Weston, Inc. (1992) prepared a "Wastewater Needs Evaluation and Plan for Southern New Castle County" for New Castle County and the Delaware Department of Natural Resources and Environmental Control. The 1992 study recommended conducting wastewater planning in southern New Castle County in accordance with 3 scenarios. Since 1992, New Castle County adopted Scenario 3 with expanded wastewater service in the northern growth area with wastewater treatment by land application at Water Farm No. 1 near Odessa and Water Farm No. 2 near Middletown.

Scenario 1 (Present Systems) Provide wastewater service to the MOT service area with proposed expansion of treatment capacity to 1.5 mgd (Figure 8).

Scenario 2 (Expand Existing Public Service Area) Expand MOT wastewater service area to treatment capacity of 2.1 mgd.

Scenario 3 (Develop New Public Service Area) Provide wastewater service to the MOT service area with proposed expansion of treatment capacity to 1.5 mgd and expand wastewater service to the Boyds Corner/Summit northern growth area between Middletown and the C&D Canal and from Route 896 east to Route 1 and Route 13 (Figure 9).

Based on mass balance modeling technique to retain nitrate levels below the drinking water standard of 10 mg/l in groundwater, the Weston study recommended minimum lot sizes for individual septic systems in southern New Castle County given local soils and climate conditions. The WATBUG nitrogen load model estimated a minimum 2 to 3-acre minimum lot size for septic systems was needed in southern New Castle County assuming a 1 in 20-year failure rate (5%) and an allowable nitrogen concentration in groundwater of 10 mg/l. Due to a high groundwater table and relatively impermeable soils, the coastal corridor from just west of Route 1/Route 13 to the Delaware Bay and the southern area between MOT and Smyrna has severe limitations for septic systems (Figure 10). Up to and including 1992, New Castle County completed 25 capital projects to replace failing septic systems that involved 500 homes at an estimated cost of $5 million or $10,000 per home.

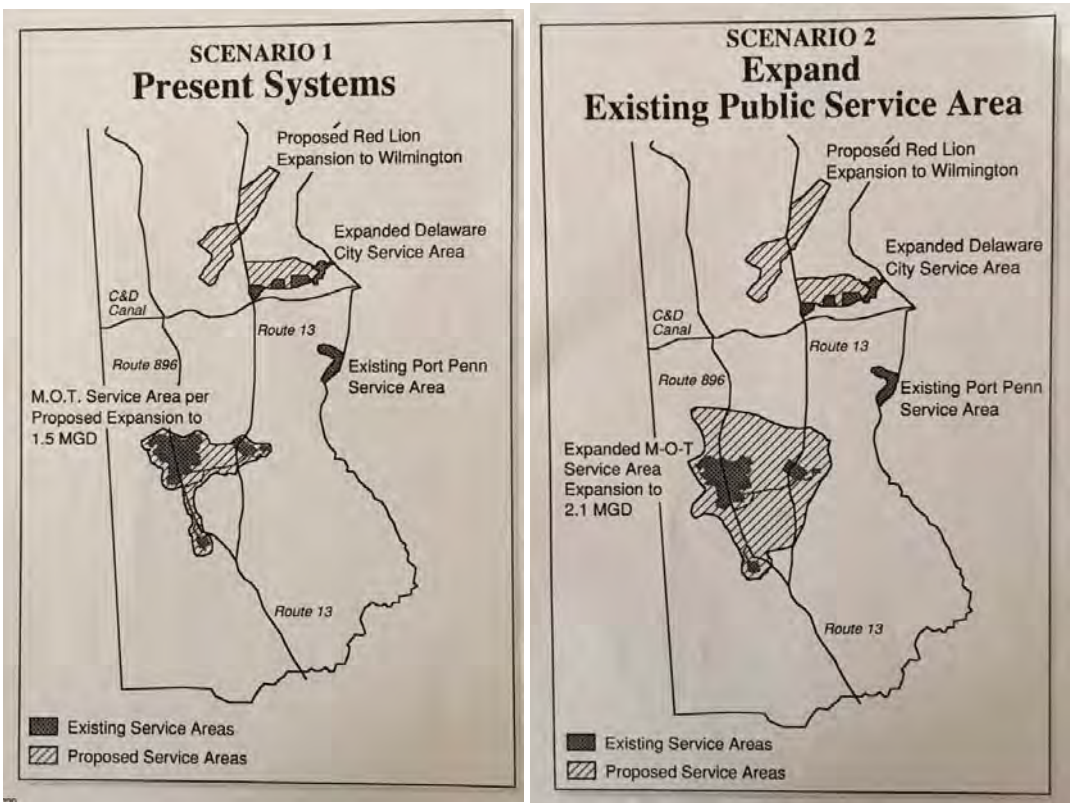


Figure 8. Wastewater service areas in southern New Castle County (Scenarios 1 and 2

Figure 9. Wastewater service area in southern New Castle County (Scenario 3)
(Roy F. Weston, Inc. 1992)

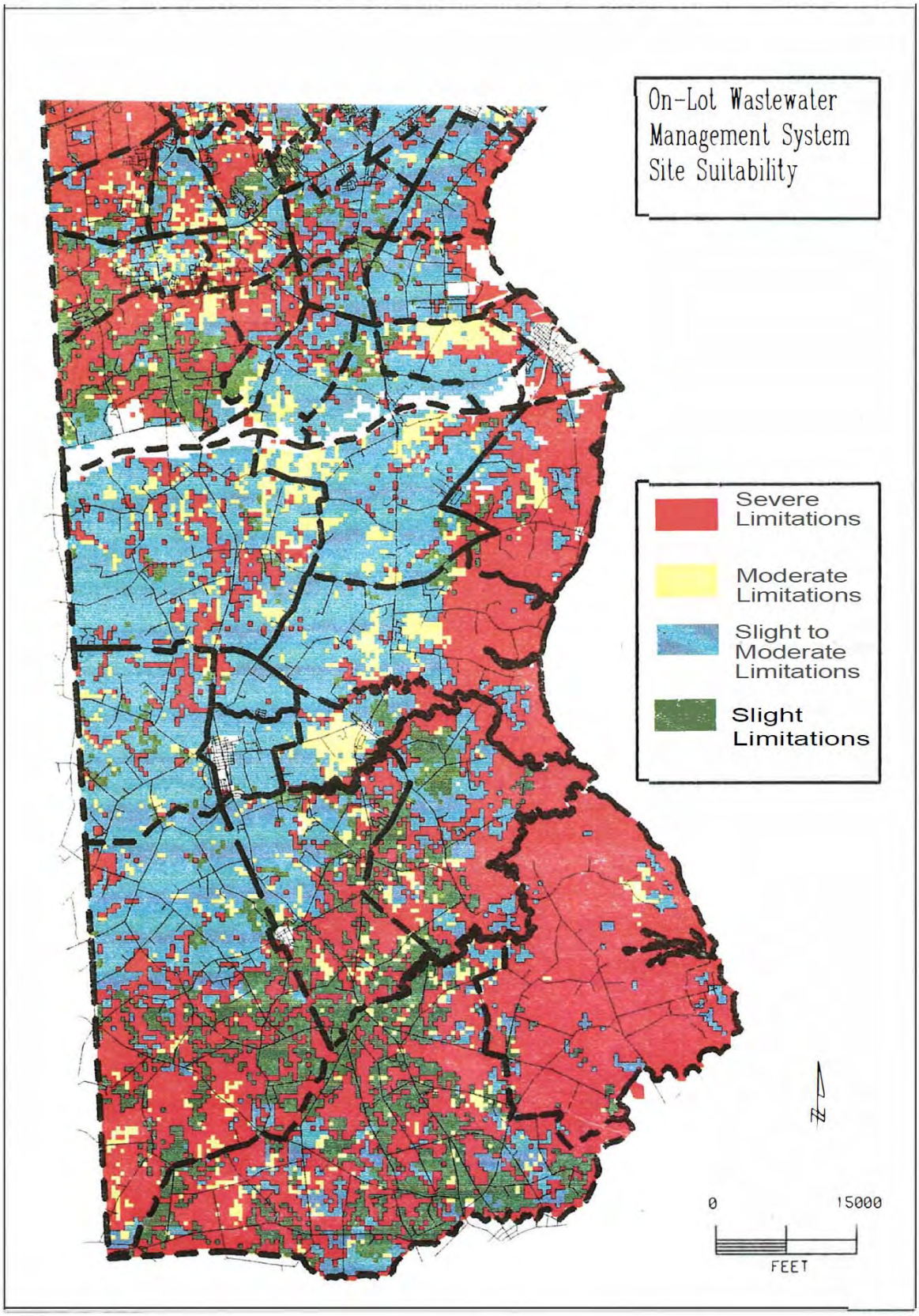


Figure 10. Soil suitability for septic system placement in southern New Castle County (Roy F. Weston, Inc. 1992)

6. Septic Systems

There are over 5,000 septic systems and over 3,000 parcels served by the public sewer system in southern New Castle County (Figure 11).

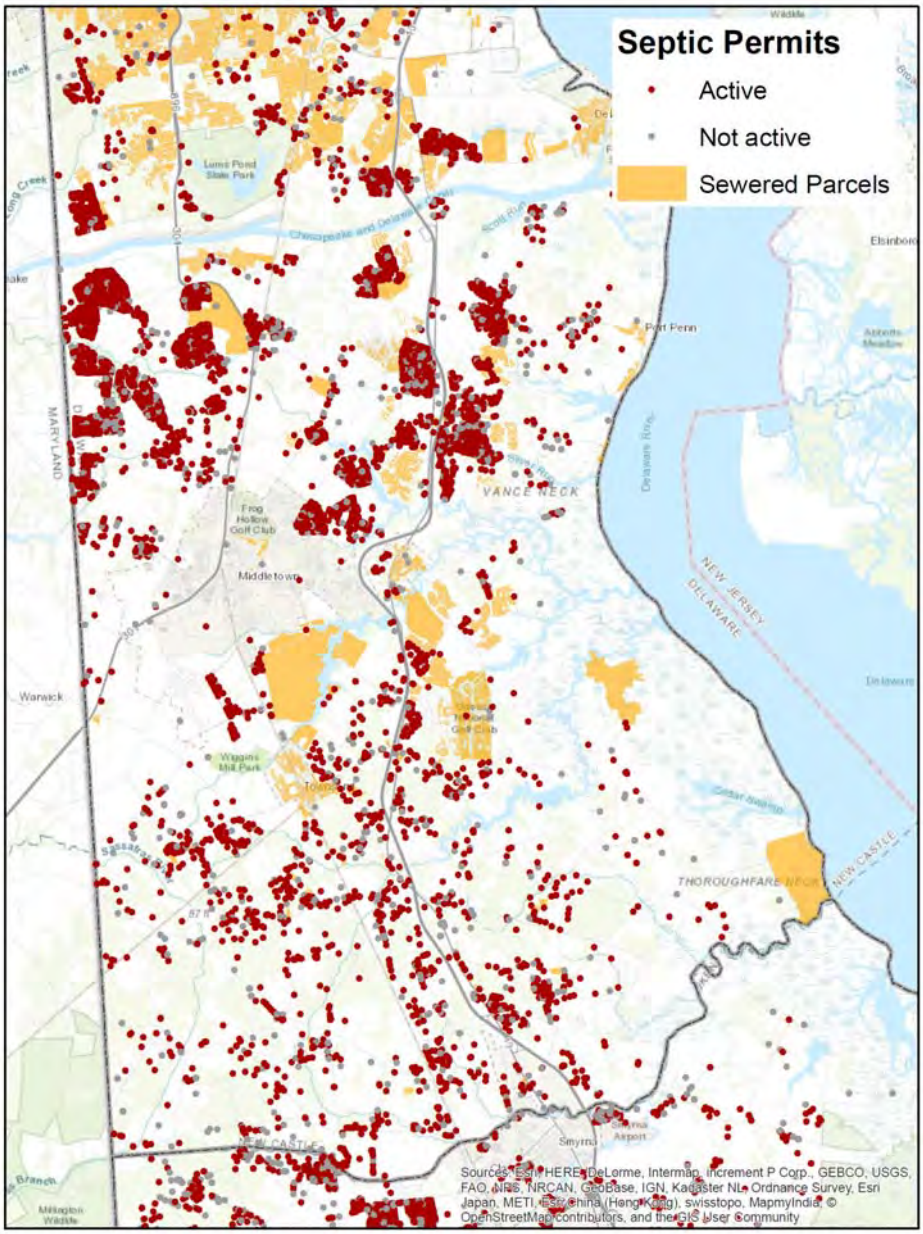


Figure 11. Septic system permits in southern New Castle County (Delaware Open Data Portal "Permitted Septic Systems" accessed Aug 27, 2017. https://data.delaware.gov/Energy-and-Environment/Permitted-Septic-Systems/mv7j-tx3u)

A review of our GIS data base indicates approximately 3,500 active septic systems and 800 inactive septic system permits are situated in the East, Middle, and West Wings of southern New Castle County between MOT and the C & D Canal (Figures 12 and 13). Table 8 lists the neighborhoods served by septic systems in southern New Castle County, several of these neighborhoods are more than 20 to 25 years old. Approximately 2,900 parcels are served by sewer and 9,600 parcels are non-sewered in the

East, Middle, and West Wings of southern New Castle County between MOT and C & D Canal (Figure 14).

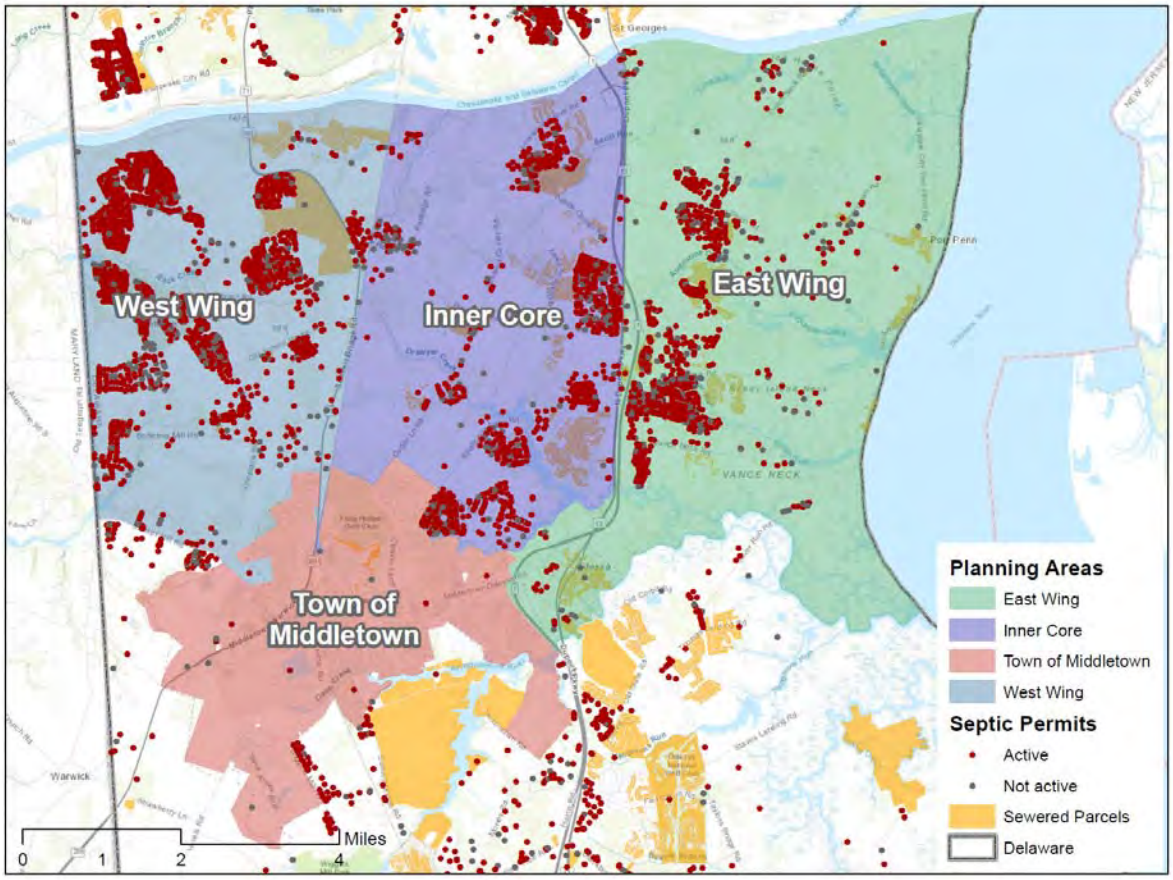


Figure 12. Septic system permits in the planning areas of southern New Castle County

Table 8. Neighborhoods served by septic systems in southern New Castle County

West Wing	Inner Core	East Wing
Back Creek	Estates and Cedar Lane	Sugar Loaf Farm
Back Creek 2	Grandview Farms	Misty Vale Farms
Bohemia Mill Pond	Brick Mill Farm	Saddle Ridge
Country Club Estates	Drawyers Creek	Great Oak Farm
Dickerson Farms	Asbury Chase II	Fairways
Fairview Farms	Mounthope	Dutch Neck Farms 2
Summit Bridge Farms	Airmont	Pine Valley Farms
Summit Field	Crystal Run Farm	Augustine Creek
	Woodlawn Estates	
	Commodore Estates	
1766 active septic systems	922 active septic systems	806 active septic systems
326 inactive septic permits	217 inactive septic permits	247 inactive septic permits
2,439 non-sewered parcels	4,432 non-sewered parcels	2,736 non-sewered parcels
302 sewered parcels	1,490 sewered parcels	1,096 sewered parcels

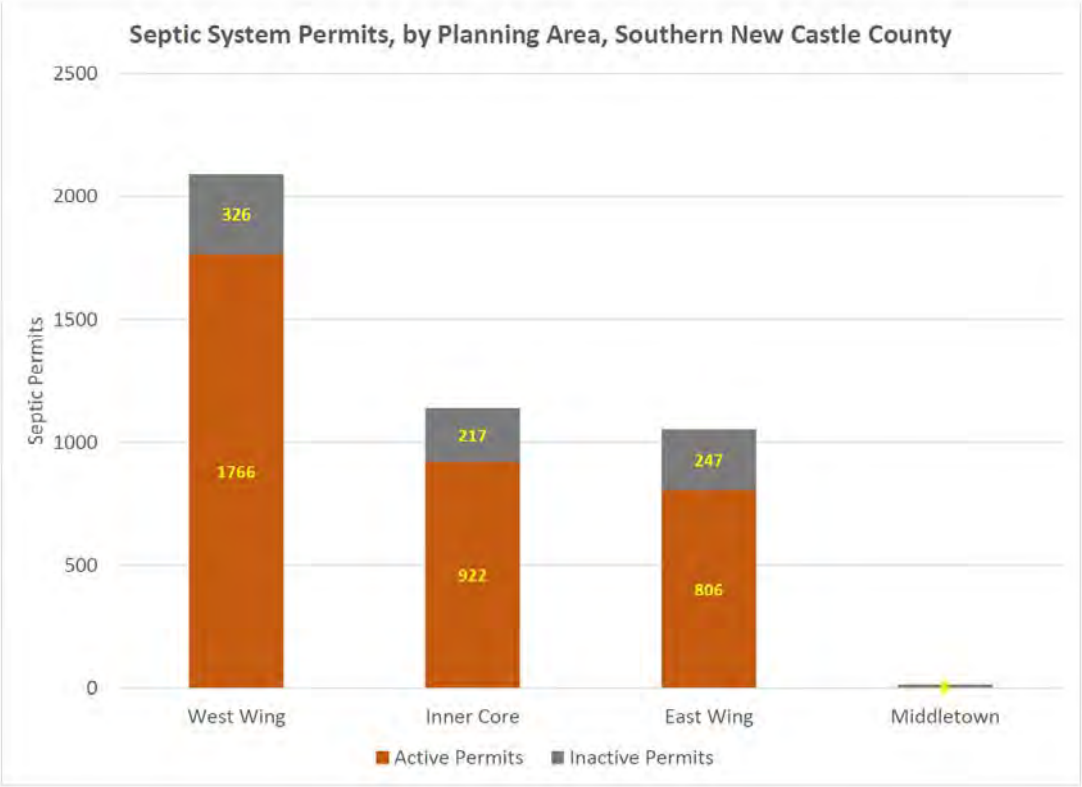


Figure 13. Septic system permits by planning area in southern New Castle County. Active septic system permits obtained from the DNREC database and includes systems in place and operating.

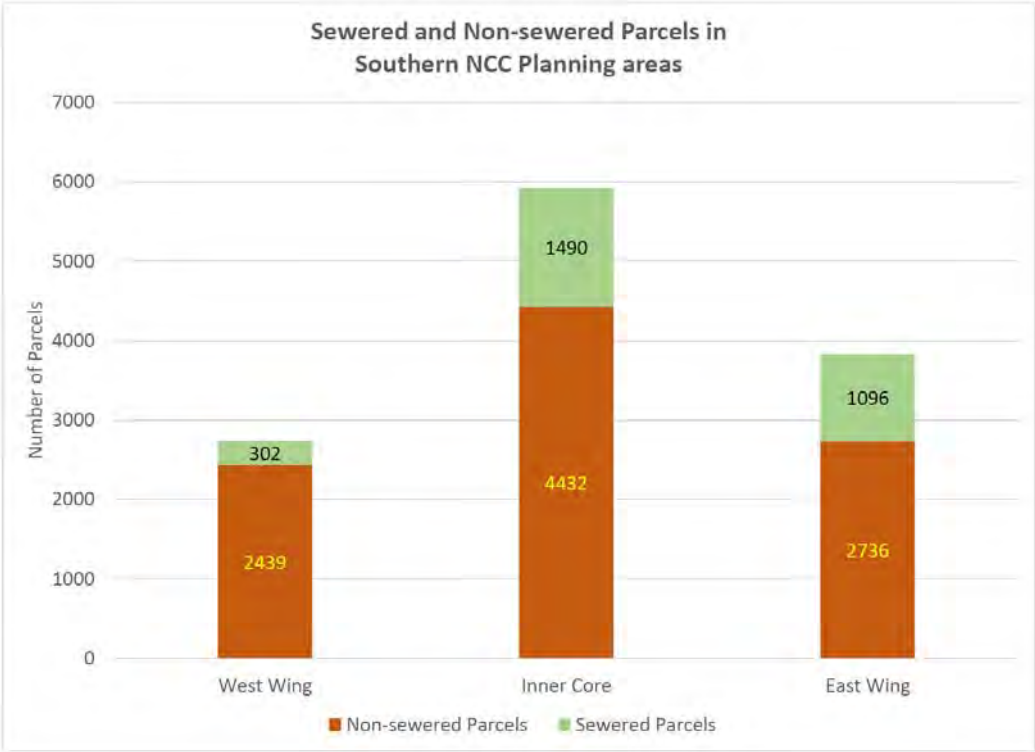


Figure 14. Sewered and nonsewered parcels by planning area in southern New Castle County

7. Septic System Suitability

Depth to Groundwater: According to GIS mapping by the Delaware Geological Survey, approximately half of southern new Castle County in the area along the Delaware River/Bay and south of Townsend has a depth to water table of 6 feet or less leaving much of this land unsuitable for septic systems (Figure 15). The State of Delaware requires a minimum distance between the septic drain field to the limiting zone (water table or clay) of 2 feet and typical dimensions of a septic tank is 4.5 ft wide by 8 ft long by 6 ft tall.

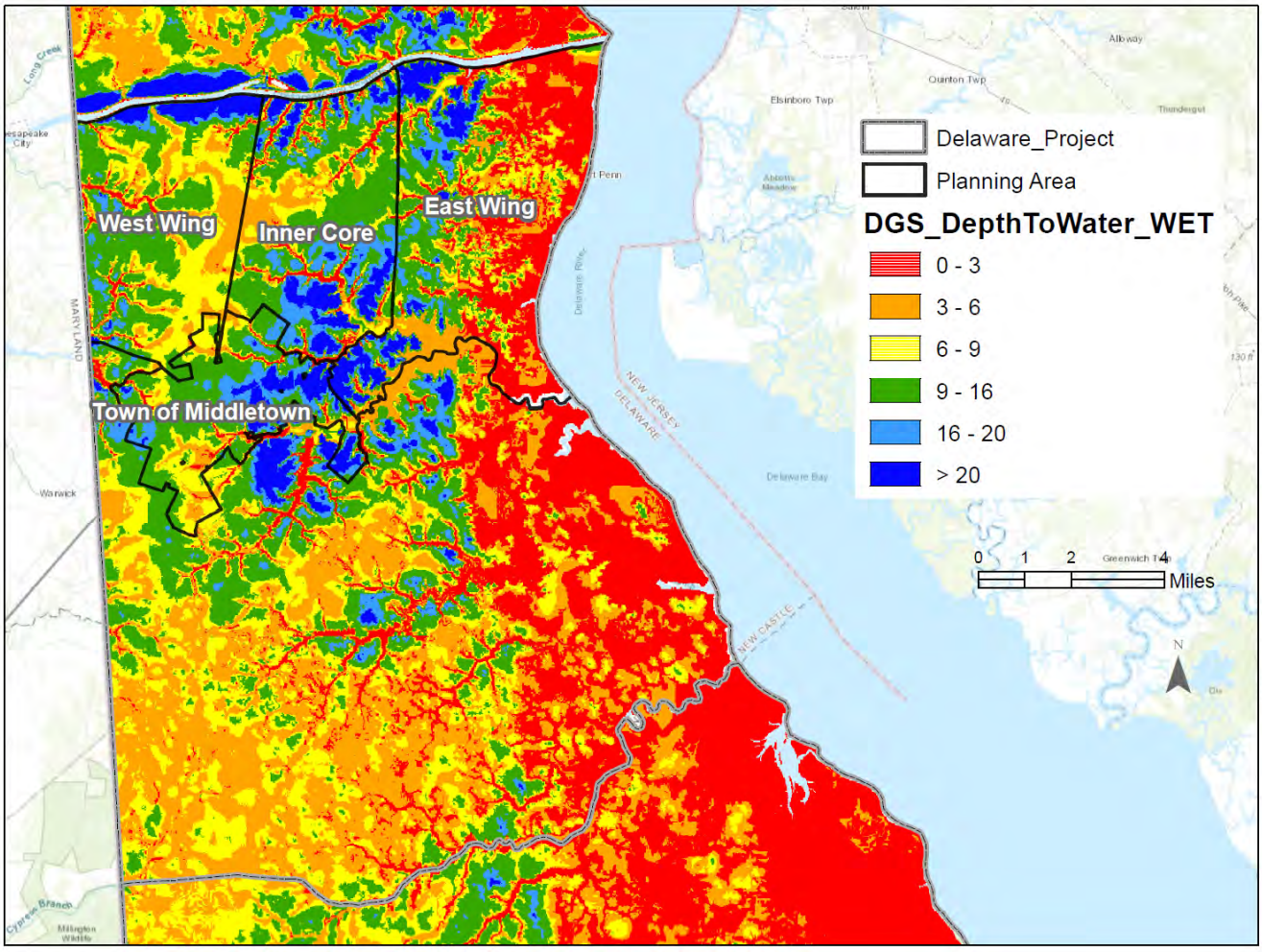


Figure 15. Depth to water table compiled by the Delaware Geological Survey.

According to the USDA Soil Survey, approximately half of southern New Castle County is covered by poorly drained Hydrologic Soil Group (HSG) D soils including hydric and wetland soils with severe limitations for septic systems (Figure 16).

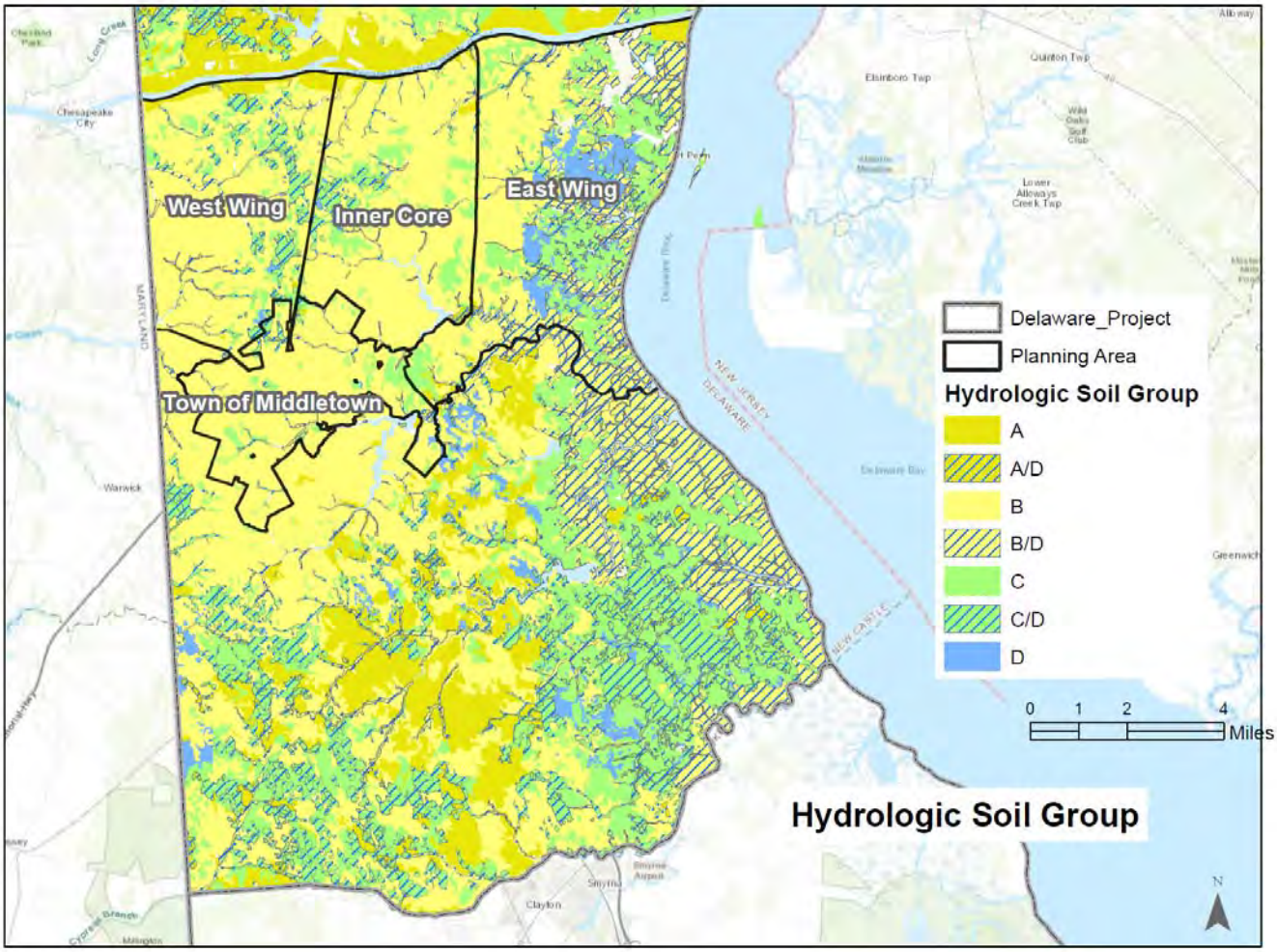


Figure 16. Hydrologic soil group map for southern New Castle County (USDA Soil Survey).

Septic systems should not be constructed on land with a high groundwater table (less than 5 to 10 ft deep). In the West Wing, Inner Core, and East Wing of southern New Castle County, 433 septic systems (10%) are on land with a shallow water table 0 to 75 cm (0 to 2.5 ft) deep, 270 systems (6%) are on land with water table 76 to 150 cm (2.5 to 5 ft) deep, and 3,581 systems (84%) are on land with water table over 150 cm (> 5 ft) deep (Figure 17 and Table 9).

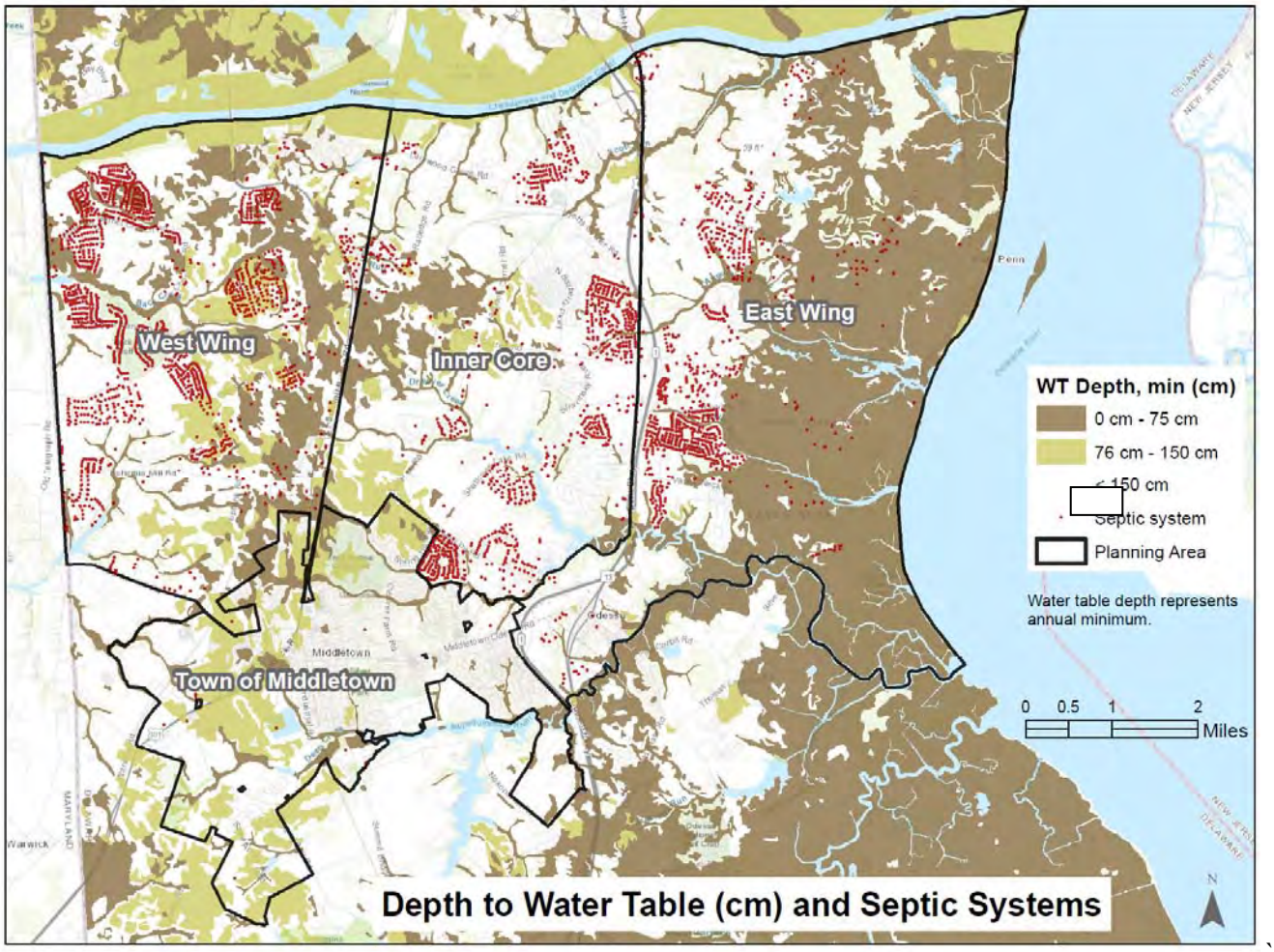


Figure 17. Depth to water table and septic systems in southern New Castle County

Table 9. Depth to water table and septic systems in southern New Castle County

Depth to Water Table (cm)	West Wing		Inner Core		East Wing		Total	
	#	%	#	%	#	%	#	%
0-75	264	13%	30	3%	139	13%	433	10%
76-150	253	12%	17	1%	0	0%	270	6%
>150	1,575	75%	1,092	96%	914	87%	3,581	84%
Total	**2,092**	**100%**	**1,139**	**100%**	**1,053**	**100%**	**4,284**	**100%**

Age of Septic Systems: The useful life of septic systems is usually around 20 years old and then these systems require replacement or renovation. In the West Wing, Inner Core, and East Wing of southern New Castle County, 610 septic systems (14%) are less than 10 years old, 1,009 systems (24%) are 10 to 20 years old, 1,309 systems (31%) are over 20 years old, and for 1,356 systems (32%) the age is unknown (Figure 18 and Table 10). Septic age in years is calculated by subtracting the date the permit was approved (if available in the database) from the current date at the time of this report.

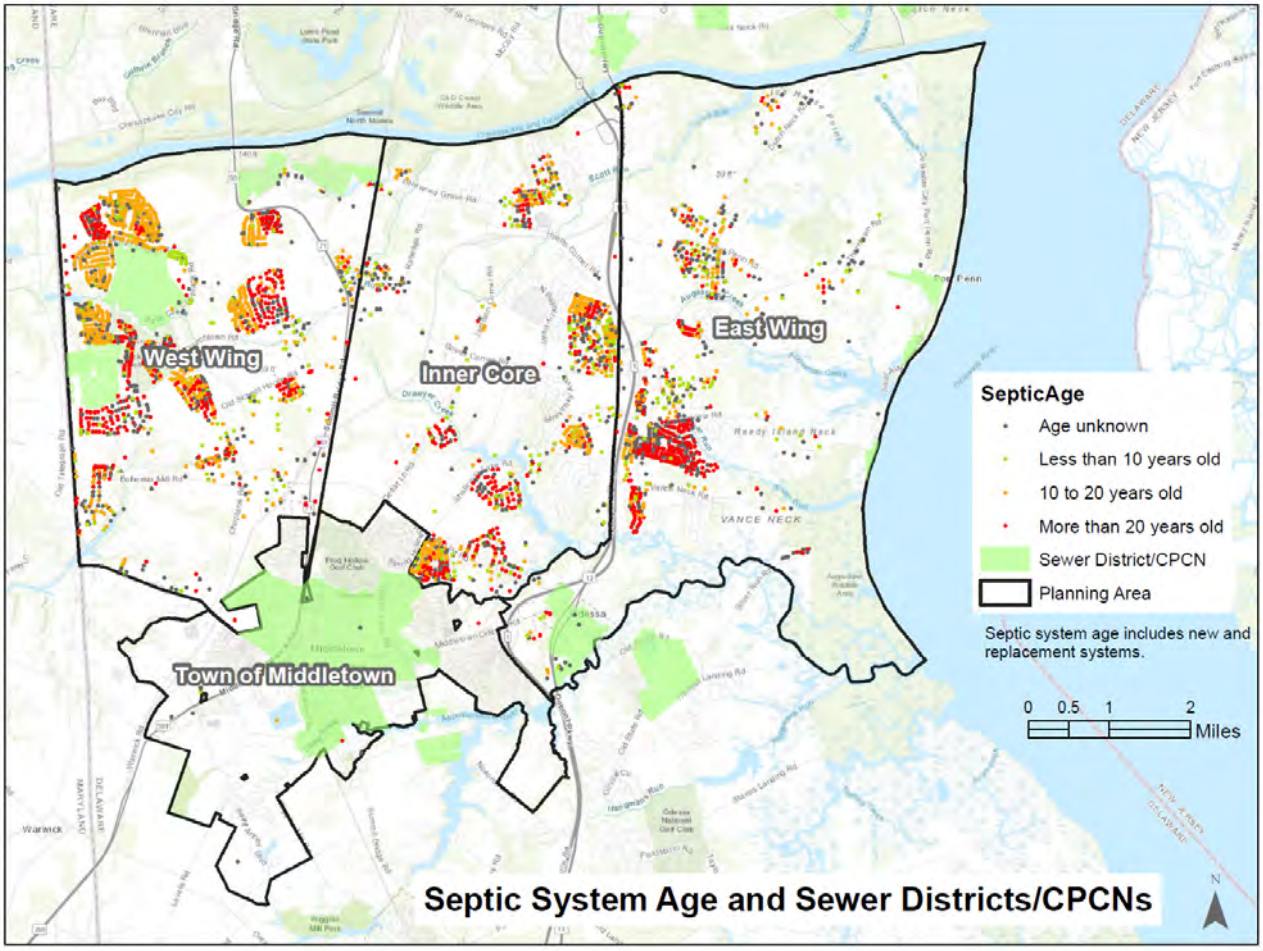


Figure 18. Age of septic systems in southern New Castle County

Table 10. Age of septic systems in southern New Castle County

Age (years)	West Wing		Inner Core		East Wing		Total	
	#	%	#	%	#	%	#	%
< 10	247	12%	197	17%	166	16%	610	14%
10-20	635	30%	229	20%	145	14%	1,009	24%
>20	613	29%	347	30%	349	33%	1,309	31%
Unknown	597	29%	366	32%	393	37%	1,356	32%
Total	**2,092**	**100%**	**1,139**	**100%**	**1,053**	**100%**	**4,284**	**100%**

Proximity to Streams: Delaware's Revised Septic System Regulations (2014) require the replacement of Septic systems within 1,000 feet from streams such as the Nanticoke River and Broad Creek to meet targets to clean up the Chesapeake Bay. In the West Wing, Inner Core, and East Wing of southern New Castle County, 1,781 septic systems (42%) are situated within 1,000 feet of streams and 2,503 systems (58%) are situated over 1,000 from streams (Figure 19 and Table 11).

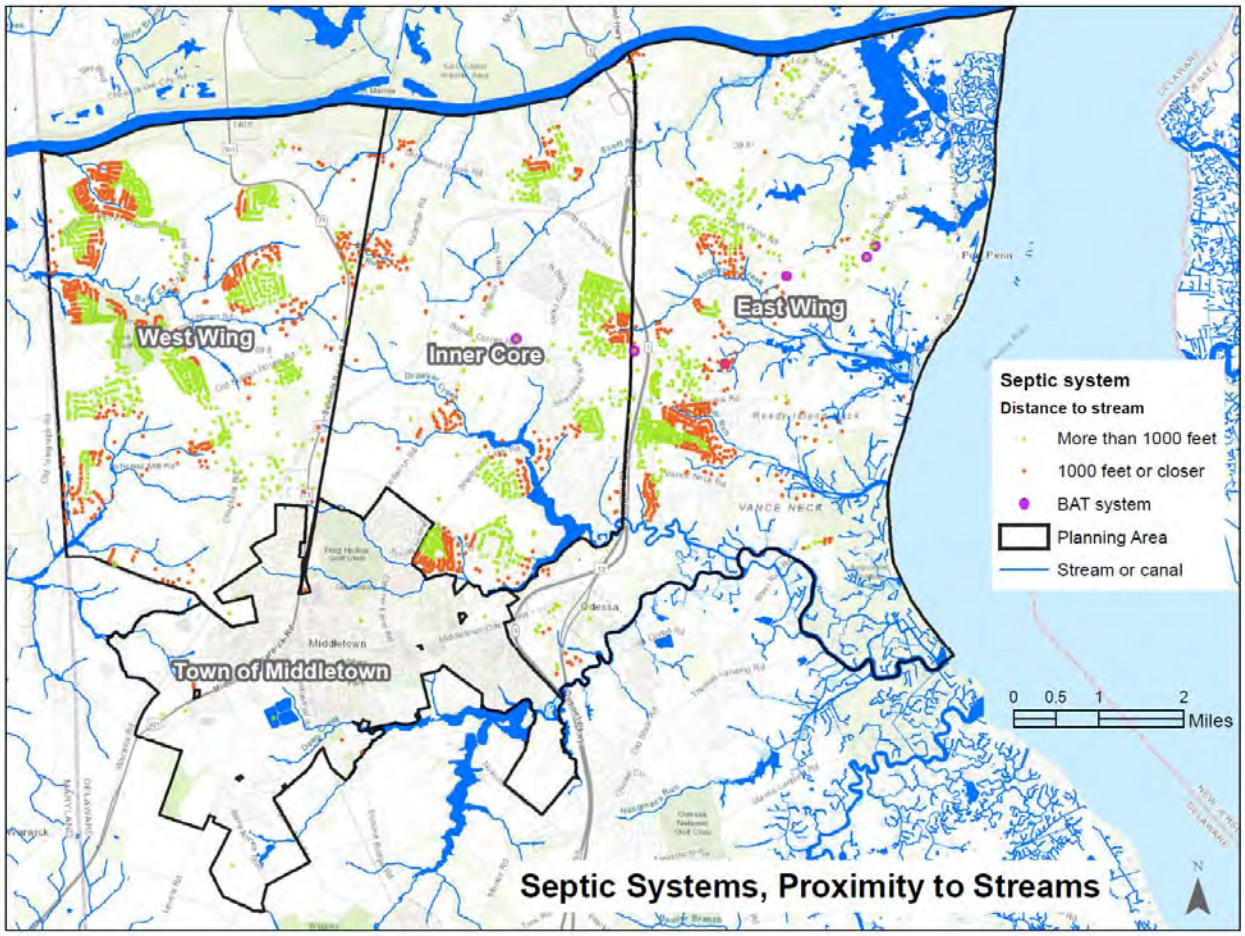


Figure 19. Septic systems and proximity to streams in southern New Castle County.

Table 11. Proximity of septic systems to streams in southern New Castle County

Distance to Stream (ft)	West Wing		Inner Core		East Wing		Total	
	#	%	#	%	#	%	#	%
0-1,000	856	41%	457	40%	468	44%	1,781	42%
> 1,000	1,236	59%	682	60%	585	56%	2,503	58%
Total	**2,092**	**100%**	**1,139**	**100%**	**1,053**	**100%**	**4,284**	**100%**

8. Comparative Analysis (Septic Systems vs. Public Sewer)

A comparison of the effect on groundwater infiltration of total nitrogen (TN) from on-site septic systems versus sewered parcels compares two hypothetical scenarios for residential development within the study areas: (1) a development of 500 single-family residential ½ acre parcels with new on-site septic disposal, and (2) the same new development connected to the central sewer service.

Septic systems, even when properly functioning transmit nutrients, such as TN, to the environment, and some amount of that ends up in the groundwater. Areas served by central sewers have less direct impact on groundwater quality, but can affect water quality once the final effluent is discharged, either to waterways or on the landscape. Sewage in the Middletown area is treated primarily at the Middletown WWTP, and effluent is ground applied across one of the town's Water Farms or spray

zones. By comparing estimated final transmission of TN to groundwater from each type of system for the hypothetical 500 household development it is possible to compare the potential nutrient impacts of each system.

The New Castle County Unified Development Code as revised allows for ½ acre lots across much of suburban southern New Castle County. While this permitted lot size is not recommended for optimum protection of groundwater resources, this analysis assumes a development of 500 single-family residential parcels of ½ acre and compares the estimated final TN delivery to the groundwater under two scenarios: 1) the parcels each have on-site septic systems and 2) the households are connected to Middletown's central sewer system, which uses land application (irrigation) to dispose of effluent. Figure 20 presents the areas of potential higher-density residential development in Southern New Castle County. The special "Neighborhood Character" districts shown in yellow allow for residential development at ½ acre lot sizes, while Suburban ("S") districts potentially allow for "Moderate to high

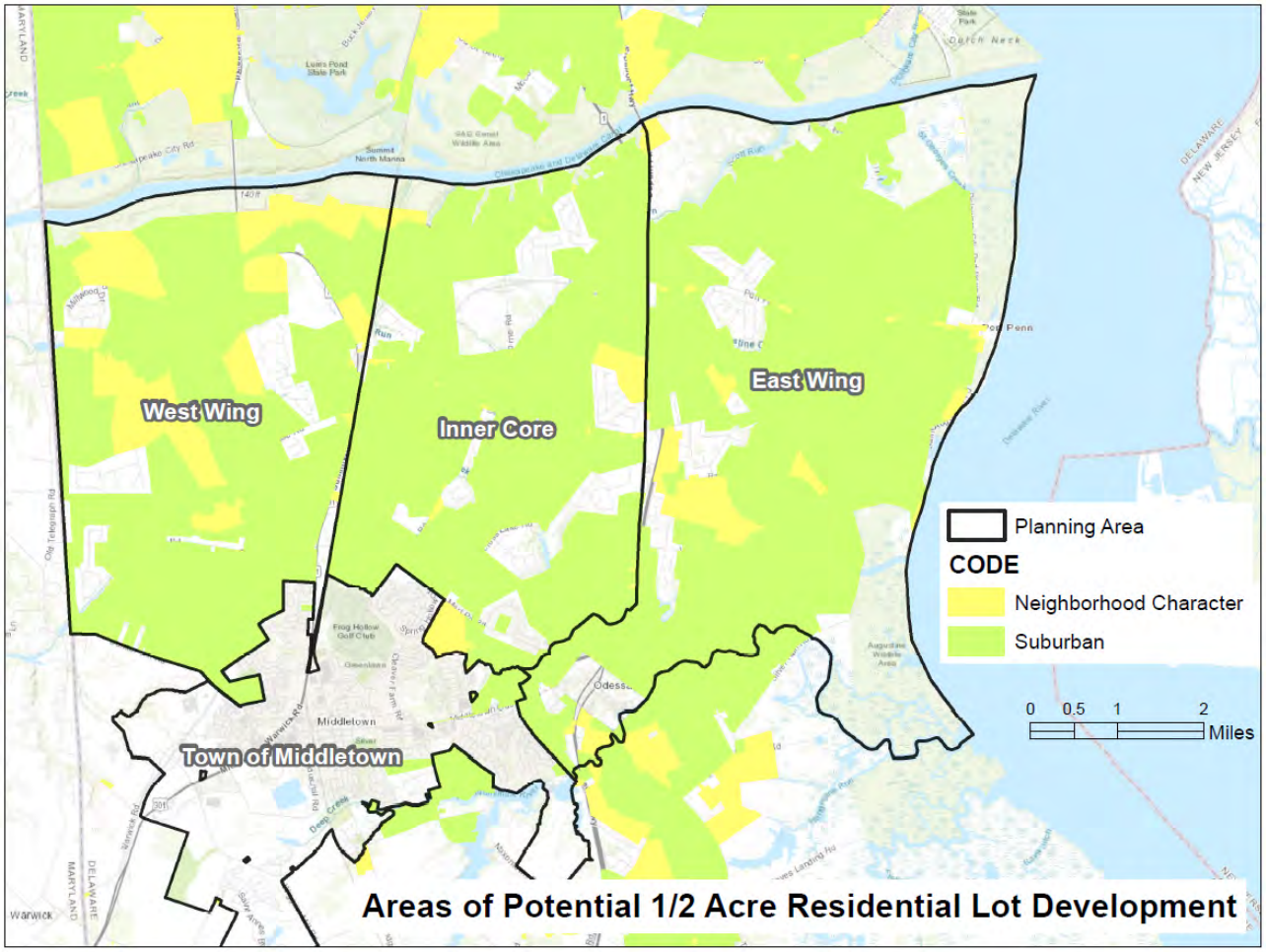


Figure 20. Planning areas in southern New Castle County

density residential" development, as long as sufficient open space is preserved to allow for a "balance of green space and buildings". This results in a wide range of potential sites in the study area that would support ½ acre lot residential development in and outside sewer districts. The U.S. Census estimates that the average household size in the Middletown-Odessa area is 3.05 people. Given 500 housing units in the hypothetical development the total number of expected residents is 1,525.

In 2016 Tetra Tech produced a report modeling the delivery of nutrients (TN) to the environment in the Chesapeake Bay watershed, based on an expert panel approach (D'Amato et al. 2016). Using the conceptual model developed in this report, it is possible to estimate the contribution to the groundwater of TN from the hypothetical 500-lot development, assuming each household has an on-site septic system.

The report identified four zones of potential attenuation in the soil layer, 1) the treatment zone, or the first soil layer where TN is attenuated, 2) the vadose, or unsaturated zone, 3) the saturated or groundwater zone where further attenuation takes place, and 4) the transition zone where groundwater enters a stream or waterway. Attenuation was determined to take place in only Zones 1 and 3. Table 12 presents the recommended attenuation values based an assumption of 5 kg/capita/year of TN produced after the effluent has passed through Zone 1.

Table 12. TN loads at edge of Zone 1 based on soil texture.

Soil Textural Grouping	USDA Soil Textures	Zone 1 TN Reduction	TN Load at Edge of Zone 1
Sandy	Sand, Loamy Sand, Sandy Loam, Loam	16%	9.2 kg/cap/yr
Loamy	Silt loam, Clay Loam, Sandy Clay Loam, Silty Clay Loam, Silt	34%	7.3 kg/cap/yr
Clayey	Sandy Clay, Silty Clay, Clay	54%	5.1 kg/cap/yr

Zone 3 attenuation is based on hydrogeomorphic region, which defines relative transmission values of Low (25% TN transmission), Medium (40% TN transmission), High (55% TN transmission), or Very High (65% TN transmission). Virtually all of the study area falls within the "Coarse Coastal Plain - Inner Coastal Plain - Dissected Outcrop Belt" region, which has a "High" (55%) transmission value for TN (Ator et al. 2005). Based on that factor Table 13 presents the final delivery value (in kg/capita/year).

Table 13. Total nitrogen loads at edge of Zone 3, based on transmissivity and soil texture.

Soil Textural Classification	USDA Soil Textures	Low TN Transmission Area	Medium TN Transmission Area	High TN Transmission Area	Very High TN Transmission Area
Sandy	Sand, Loamy Sand, Sandy Loam, Loam	1.1 kg/cap/yr	1.7 kg/cap/yr	2.3 kg/cap/yr	2.7 kg/cap/yr
Loamy	Silt loam, Clay Loam, Sandy Clay Loam, Silty Clay Loam, Silt	0.8 kg/cap/yr	1.3 kg/cap/yr	1.8 kg/cap/yr	2.1 kg/cap/yr
Clayey	Sandy Clay, Silty Clay, Clay	0.6 kg/cap/yr	0.9 kg/cap/yr	1.3 kg/cap/yr	1.5 kg/cap/yr

Since the study area is predominantly loamy soil types, the delivery value for the hypothetical 500-lot subdivision is 4.0 lb TN/capita/yr. Based on the expected population in a 500-unit residential development (1,525), the total impact on the receiving waters is 6,000 lb TN/yr.

Much of the study area (East, Central, and West Wings) connected to central sewer is served by the MOT WWTP, which uses land application (irrigation) to deliver treated effluent to the environment at publically-owned land and private farms.

The addition of 500 housing units to this system will result in delivery of additional TN load to the groundwater and receiving waterways. By using information from the MOT WWTP measuring TN levels in the percolate it is possible to estimate the effect, in terms of TN load of the hypothetical 500-unit development served by the MOT WWTP.

Based on information from the Delaware Wastewater Study System Report for the MOT WWTP (DNREC 2010) the average daily flow at the facility is 0.57 mgd with 90% of the flow coming from domestic sources. The total population served is 11,986, so the total per capita flow is 42.8 gal/capita/day. For the expected number of people (1,525) in a hypothetical 500-unit development, the expected flow will be 65,270 gal/day. The 2017 data from the MOT WWTP assessment of TN balance indicates that the total annual load of TN delivered to the groundwater is 87 lb/ac/yr in 7,560,557 gallons/ac/yr of percolate, for a total of 1.14×10^{-4} lb/gal of TN. Therefore, the total daily load of TN to the groundwater from the 500-unit development through spray irrigation is 273 lb/yr. This value represents a 95% reduction of TN impact on the watershed (Table 14).

Table 14. Comparison of TN loads from 500-unit residential subdivision, on septic v. sewer.

Hypothetical 500-unit Residential Development TN Delivery to the Environment			
On-site Septic		**Central Sewer (MOT WWTP)**	
17	lb/day	0.7	lb/day
6,052	lb/yr	273	lb/yr
Reduction (Sewer vs. Septic)		**95%**	

9. Public Water Supply

The following water systems (Figure 21) provide drinking water in southern New Castle County according to the Ninth Report to the Governor and General Assembly Regarding the Progress of the Delaware Water Supply Coordinating Council, Estimates of Water Supply and Demand in Southern New Castle County through 2030 (2006).

Public Community Wells
- Artesian Water Company (26 wells)
- Artesian Water Company, Delaware Correctional Center (4 wells)
- Tidewater Utilities (24 wells)
- Town of Middletown (4 wells)
- Mount Pleasant Trailer Park (2 wells)
- Cantwell Water Company (2 wells)

Self-Supplied Non-Community Wells (20 wells)
- Transient: Restaurants, stores, hotels, parks
- Non Transient: Schools, daycare centers, office, factories

Residential Individual Wells (4,600 wells)

Irrigation Water Supplies
- Farms (26 wells)
- Golf courses, nurseries (1 well)

A DNREC GIS database indicates over 3,100 individual wells are dispersed across southern New Castle County north of the MOT area with 434 potable and 215 nonpotable wells in the West Wing, 796 potable and 310 nonpotable wells in the Inner Core, 857 potable and 138 nonpotable wells in the East Wing, and 105 potable and 245 nonpotable wells in Middletown (Figures 22 and 23).

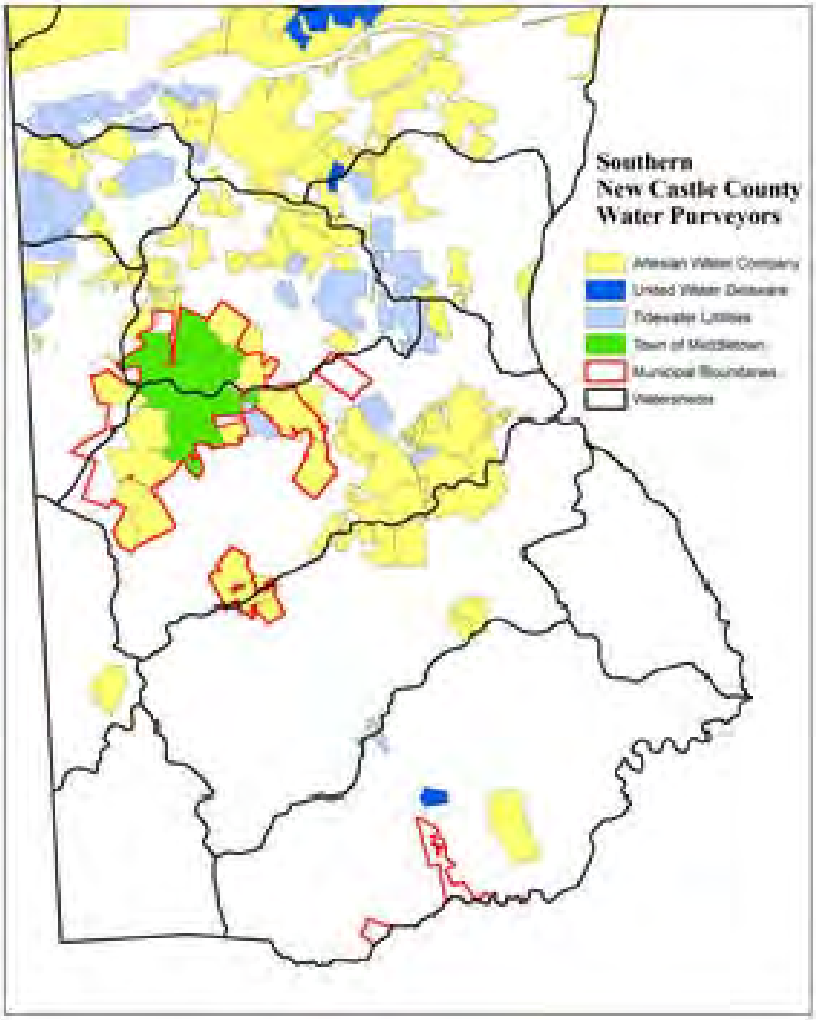


Figure 21. Public water supply franchise areas in southern New Castle County

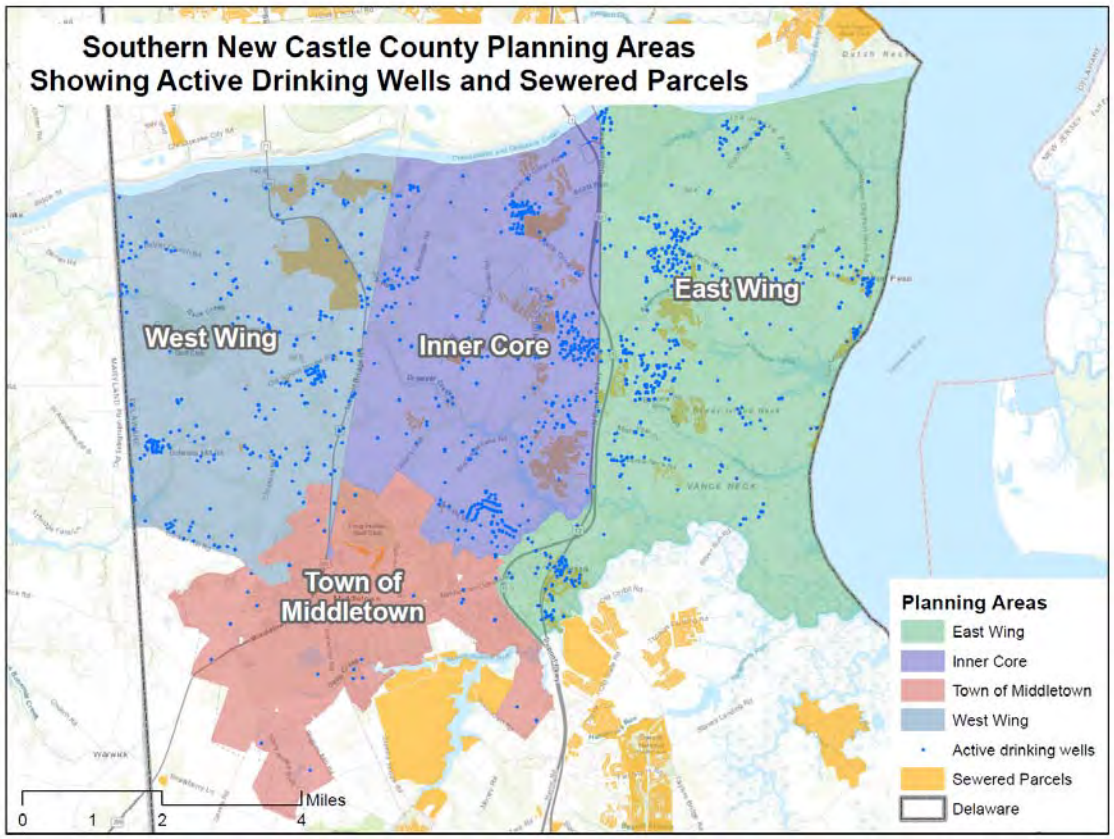


Figure 22. Individual wells in southern New Castle County

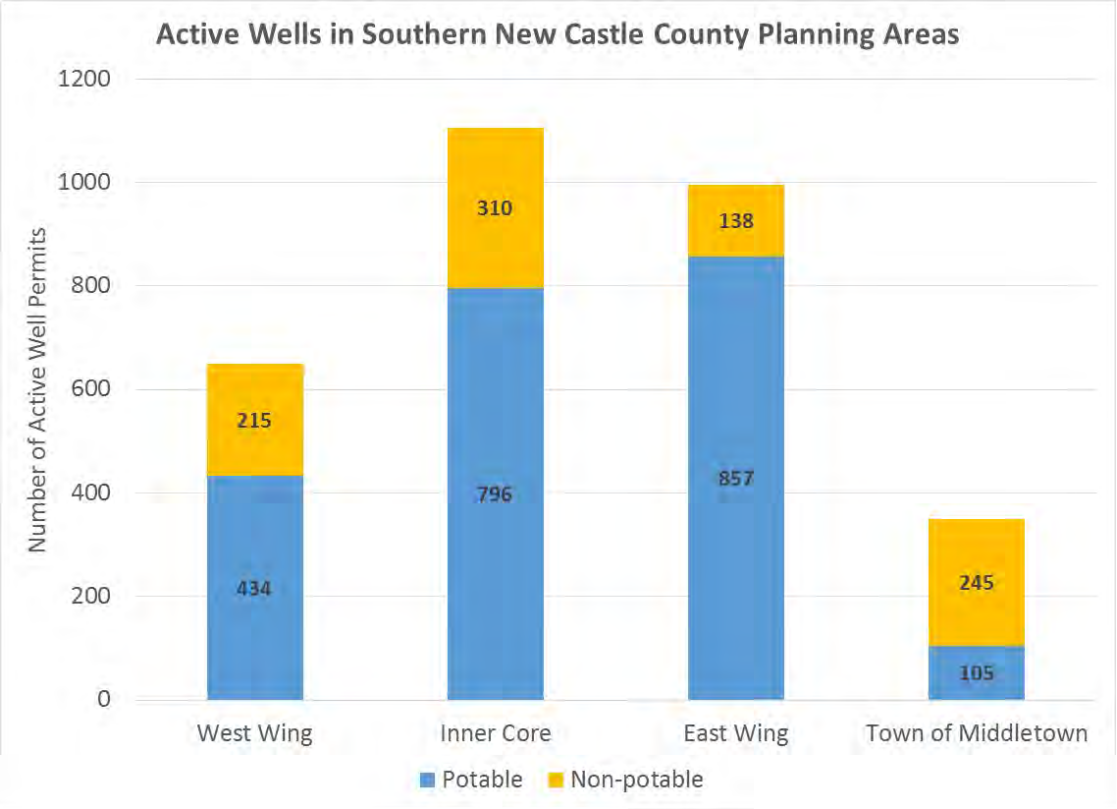


Figure 23. Active individual wells in southern New Castle County planning areas

10. Conclusions

1. Septic systems usually last for about 20 years and can properly treat wastewater in rural areas provided these systems are situated on large lots (> 2 acres) with permeable soils (> 1 in/hr) and a deep water table (>= 10 ft) and are pumped out every 2 to 3 years by property owners. Of 20,000 acres of agricultural land expected in southern New Castle County by 2030, 10,000 acres or 5,000 lots at 2 ac/unit are situated on land with adequate depth to water table (>= 10 ft) with infiltration rates >1 in/hr with adequate septic system suitability.

2. Population in southern New Castle County is projected to increase from 67,499 in 2015 to 90,376 by 2030 or by 11.8% from 2015 to 2020 and another 19.7% from 2020 to 2030. About 10,000 people or 13% of the population in southern New Castle County utilize septic systems.

3. The WATBUG nitrogen load model estimated a minimum 2 to 3-acre min lot size for septic systems was needed in southern New Castle County assuming a 1 in 20-year failure rate (5%) and allowable nitrogen concentration in groundwater of 10 mg/l. Several years ago, New Castle County Code was amended to remove minimum lot size requirements for unsewered lots (1 acre on private wells and ¾ acre on public water systems). The revised code specifies that DNREC regulations govern septic system approvals in New Castle County including ½ lot minimum which is the statewide standard. Kent County allows septic systems in 1, 2, 3, and 4 acre lots based on zoning classification. Sussex County allows septic systems on ½ acre lots with public water and ¾ acre lots with individual wells. Maryland requires min. 20,000 sq. ft lots on septic systems.

4. Peak wastewater flow in southern New Castle County is projected to increase from 4.5 mgd in 2006 to 12.1 mgd by 2030 assuming 25,244 dwelling units will be constructed at 1.0 du/ac. In 1992, New Castle County adopted Scenario 3 to provide wastewater to the MOT service area, expand treatment capacity to 1.5 mgd by land application at Water Farm No. 1 near Odessa and Water Farm No. 2 near Middletown and expand wastewater service to the Boyds Corner/Summit northern growth area between Middletown and C&D Canal and Route 896 east to Route 1/13.

5. Due to high groundwater table and impermeable soils, USDA and DGS soil mapping indicate half of the land in southern New Castle County in the Delaware Bay coastal corridor east of Routes 1 and 13 and south of MOT to Smyrna has severe limitations for septic systems.

6. By 1992, New Castle County completed 25 capital projects to replace failing septic systems that involved 500 homes at an estimated cost of $5 million or $10,000 per home. In Maryland the septic system retrofit hookup cost to WWTP ranged from 15,000 - $35,000.

7. The East, Middle, and West Wings of southern New Castle County between MOT and C & D Canal holds:
   - 3,500 active septic systems and 800 inactive septic system permits are situated in
   - 2,900 parcels served by sewer and 9,600 parcels are non-sewered
   - 433 septic systems (10%) are on land with a shallow water table 0 to 2.5 ft deep, 270 systems (6%) have water table 2.5 to 5 ft deep, and 3,581 systems have water table over 5 ft deep.
   - 610 septic systems (14%) are < 10 yr old, 1,009 (24%) are 10-20 yr, 1,309 (31%) are > 20 yr old.
   - 1,781 septic systems (42%) are < 1,000 feet and 2,503 systems (58%) are > 1,000 ft of streams.

8. The Chesapeake Bay Watershed Implementation Plan (2010) set maximum septic system nitrogen load allocations of 28,000 lb/year or 20% of the N load in the Elk River, C&D Canal, Bohemia River, and Sassafras River watersheds in southern New Castle County. Nitrogen allocations from septic systems in the Chesapeake Bay watershed in Delaware are 262,663 lb/year or 11% of the total load to the Bay. The Chesapeake Bay WIP in Maryland concluded new homes on septic systems generate 5 times more N load than homes in sewer areas. Septic systems cause 10 times more pollution to Chesapeake Bay compared to public sewer.

9. The 2012 Maryland Septic Act is expected to produce these statewide benefits over 25 years:
   - Reduce 50,000 new septic systems
   - Prevent the loss of about 100,000 acres of forest and farmland
   - Large-lot development on septic (2 ac/lot on average)
   - Reduce about 1 million pounds of nitrogen from entering local streams and Chesapeake Ba
   - In Maryland in 2009, homes on septic systems cost $50,000 more than homes on sewer.

10. The 3,500 septic systems in southern New Castle County discharge 81,200 lb of nitrogen to the environment or 10 times more than homes on public sewer. According to the Chesapeake Bay model, an average home with 2.63 persons discharges 23.2 lb. of wastewater to the environment.

11. A comparative analysis of total nitrogen loads from a 500-unit residential subdivision in southern New Castle County indicates central sewer in the MOT WWTP area would deliver 273 lb/yr of nitrogen to groundwater or 95% less than septic systems that would deliver 6,052 lb/yr of nitrogen.

12. Over 3,100 individual water wells are dispersed across southern New Castle County north of MOT with 434 potable/215 nonpotable wells in the West Wing, 796 potable/310 nonpotable wells in the Inner Core, 857 potable/138 nonpotable wells in the East Wing, and 105 potable/245 nonpotable wells in Middletown.

11. Recommendations

The University of Delaware Water Resources Center recommends that amendments to the 2012 New Castle County Comprehensive Development Plan and Unified Development Code should include the following provisions.

1. Include a detailed map delineating the boundaries of the southern New Castle County sewer area that focuses on the northern growth area between MOT and the C&D canal and includes the sanitary sewer system network (existing/planned), septic systems, sewered parcels, planned developments, and wastewater treatment facilities.

2. Over 3,500 active septic systems and almost 800 inactive septic system permits are situated in the East, Middle, and West Wings of southern New Castle County between MOT and the C & D Canal. The Comprehensive Plan should include specific provisions for a septic system relief program to connect sewer to aging neighborhoods (over 20 years old) in the growth area between MOT and the C &D Canal in southern New Castle County. In 1992 the cost of septic system relief was $10,000 per home. The 2012 Comprehensive Plan lists the septic relief cost at $25,000 per dwelling.

3. Given that 32% of the septic systems in southern New Castle County are of unknown age and that age is important for determining threat to groundwater, future costs, and time horizons, the DNREC

should be requested to update its septic system data base to determine the age of these unknown septic systems.

4. New Castle County should amend the Unified Development Code to restore minimum lot density, depth to water table, and soil provisions for septic systems. Based on nitrogen loading models, the minimum lot size for septic systems in southern New Castle County should be 2 ac/du. Minimum soil permeability should be 1 in/hr and minimum depth to groundwater table should be at >= 10 ft. Figure 24 presents a map of septic system limitations in south New Castle County.

5. Due to a high groundwater table, the coastal corridor from east of Route 1 and Route 13 to the Delaware Bay and south of MOT to Smyrna has severe limitations for septic systems. Therefore, future growth should be focused in the public sewer area between MOT and the C&D Canal and from the DE/MD state line in the west to the Route 1/Route 13 corridor to the east. Sanitary sewer infrastructure should be extended only within this defined public sewer area and only beyond to hook up sewer to neighborhoods with aging and failing septic systems.

6. To protect the quantity and quality of aquifers that provide sole source drinking water and to manage water supplies by the principles of contiguity and compactness it is preferable that subdivisions should be served by public water systems rather than by individual wells. The New Castle County Unified Development Code (Section 40.12.115) appropriately requires that subdivisions with more than 25 lots should be served by public water systems. New Castle County should work with public water suppliers to hook up public water systems to neighborhoods with more than 25 lots that are presently served by individual wells to bring these areas in to compliance with the UDC. As with public water systems, large developments greater than 25 lots should be hooked up to public sewer systems to be properly managed and operated over the long term by New Castle County.

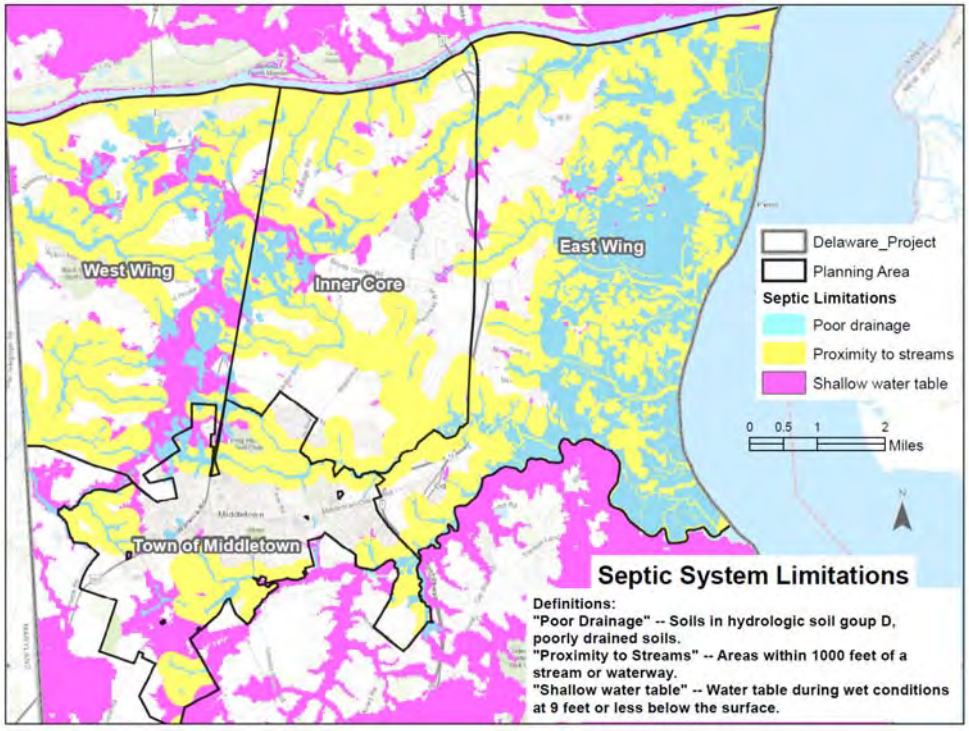


Figure 24. Septic system limitations in southern New Castle County

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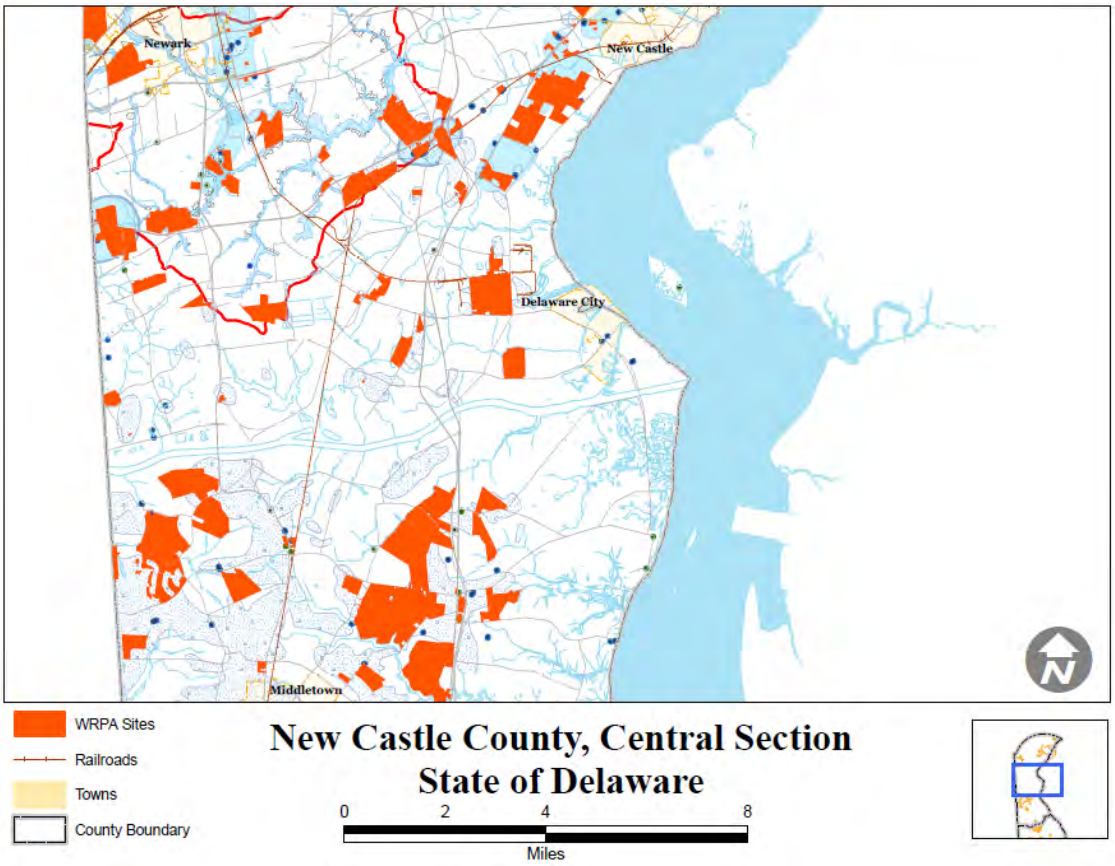
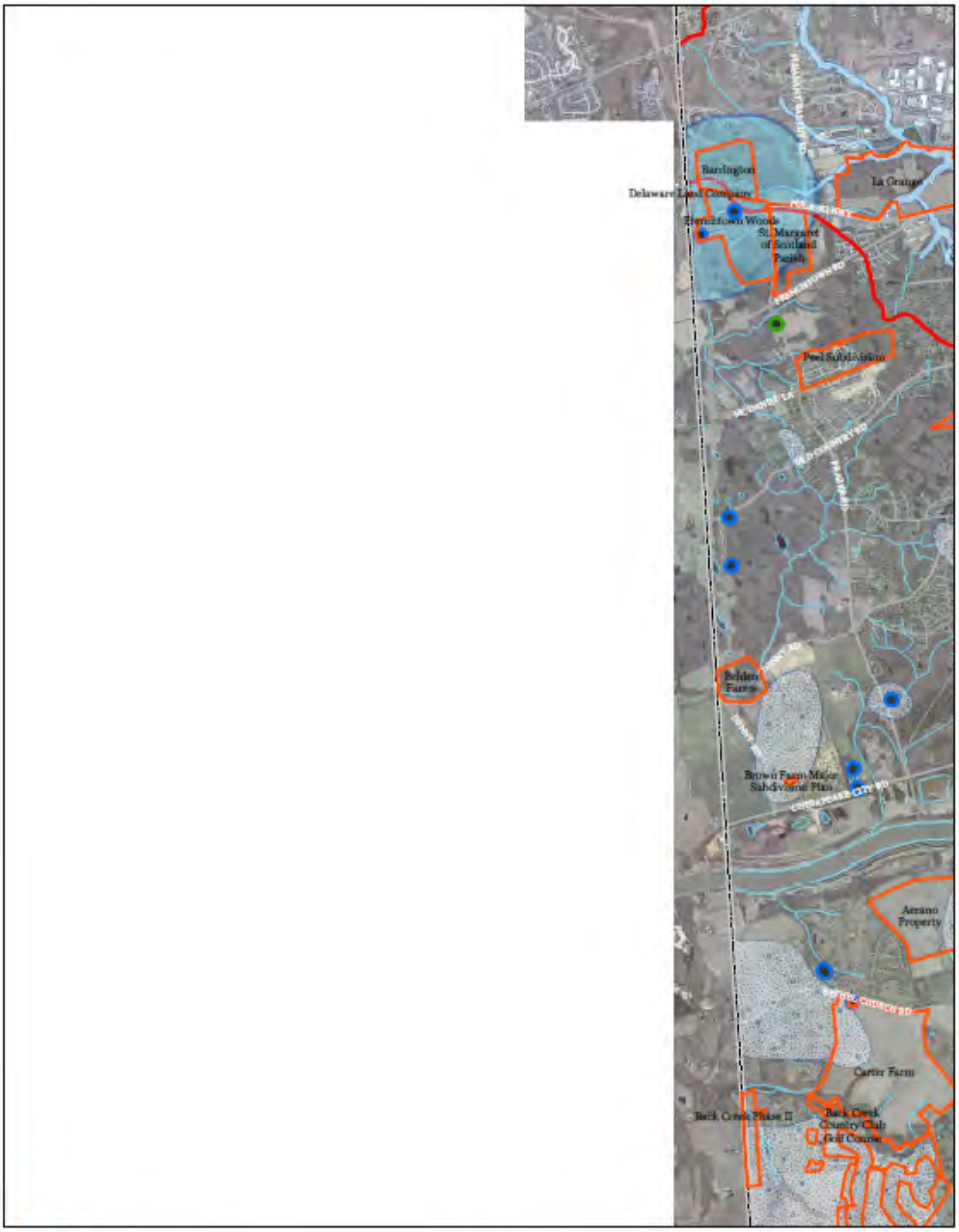
Appendix

Back Creek Country Club was constructed in a Recharge Water Resource Protection Area (WRPA) during the early 1990s in two phases, Phase I of 239 acres with 6% impervious cover and Phase II of 346 acres with 8% impervious cover, well below the 20% impervious cover standard. Predevelopment groundwater monitoring conducted in 1990-1994 before the neighborhood and golf course were constructed indicate nitrogen levels ranged from 10 to 20 mg/l, above the drinking water standard of 10 mg/l. Predevelopment (agricultural) groundwater nitrogen loading rates were calculated as 15,391 lb/yr, higher than the post development loading of 11,989 lb/yr (golf course fertilization 7,189 lb/yr and 202 lots w/septic systems 4,799 lb/yr).

Project Name	Area (ac)	% Impervious	Watershed	WRPA	Predevelop. N Loading (lb/y)	Postdevelop N Loading (lb/yr)
Back Creek C. C.	239/346	6% - 8%	C & D Canal	Recharge	15,391	11,989

Application	Mon. Well	Date Initial	Date	N 12/90 (mgl)	N 3/94 (mgl)
Back Creek	MW1	12/90	3/94	13	15
	MW2	12/93	3/94	10	20
	MW3	12/93	3/94	14	13
	MW4	12/93	3/94	14	15


Newark
New Castle
Delaware City
Middletown
WRPA Sites
Railroads
Towns
County Boundary
New Castle County, Central Section
State of Delaware
0
2
4
8
Miles


Barrington
Delaware Land Company
La Grange
Glenwood Woods
St. Margaret of Scotland Parish
Peel Subdivision
Belden Farms
Brown Farm Major Subdivision Plan
Arrano Property
Cartier Farm
Back Creek Phase II
Back Creek Country Club Golf Course
WRPA Sites
Railroads
Towns
County Boundary
Elkton
0 0.5 1 2
Miles
5 6 7
10 11
12 13 14

DUFFIELD ASSOCIATES, INC.
BACK CREEK NITROGEN LOADING TO GROUNDWATER CALCULATIONS

W.O.# 2480.CD
CALCULATED BY: LDK
DATE: 5-18-94

CHECKED BY:
DATE:

EXISTING CONDITIONS:

COVER TYPE	AREA (ACRES)	NITROGEN APPLICATION RATE (LBS/AC/YR)	APPLIED NITROGEN LOADING (LBS/YR)	GROUNDWATER NITROGEN LOADING (LBS/YR)
CORN CROPS	240.96	200.00	48192.00	14457.60
SOYBEAN CROPS	120.48	0.00	0.00	0.00
GRASS	23.91	130.00	3108.30	932.49
WOODS	59.20	0.00	0.00	0.00
ROADS	3.22	0.00	0.00	0.00
BUILDINGS	0.23	0.00	0.00	0.00
TOTAL =	448.00		51300.30	15390.09

ASSUMPTIONS:
1. CULTIVATED ACREAGE IS PLANTED IN CORN FOR TWO YEARS AND SOYBEANS FOR ONE YEAR ON A ROTATING BASIS.
2. NITROGEN APPLICATION FOR CORN IS 200 POUNDS PER ACRE PER YEAR.
3. NITROGEN APPLICATION FOR SOYBEANS IS 0 POUNDS PER ACRE PER YEAR.
4. NITROGEN APPLICATION FOR GRASS IS 130 POUNDS PER ACRE PER YEAR.
5. GROUNDWATER NITROGEN LOADING FOR FERTILIZATION FROM CULTIVATED LANDS AND GRASS AREA TYPICALLY = 30% OF APPLIED NITROGEN LOADING.

INTERMEDIATE CONDITIONS – ENTIRE SITE

NITROGEN LOADING THROUGH FERTILIZATION

COVERAGE TYPE	AREA (ACRES)	NITROGEN APPLICATION RATE (LBS/AC/YR)	APPLIED NITROGEN LOADING (LBS/YR)	GROUNDWATER NITROGEN LOADING (LBS/YR)
RESID. LAWNS	141.31	130.00	18370.30	2755.54
CORN	73.90	200.00	14780.00	4434.00
SOYBEANS	73.90	0.00	0.00	0.00
GRASSED AREA	68.06	0.00	0.00	0.00
WOODS	59.20	0.00	0.00	0.00
BLDGS & ROADS	31.63	0.00	0.00	0.00
TOTAL=	448.00		33150.30	7189.55

NITROGEN LOADING THROUGH SEPTIC SYSTEMS

NUMBER OF LOTS = 202
AVERAGE NUMBER OF PEOPLE PER LOT = 3
NITROGEN RATE = 8.80 LBS/PERSON/YR
NITROGEN LOADING = 202 LOTS X 3.0 PEOPLE PER LOT X 8.80 LBS/PERSON/YR
= 5332.80 LBS/YR
GROUNDWATER NITROGEN LOADING = 90% X 5332.80 LBS/YR
= 4799.52 LBS/YR

TOTAL NITROGEN LOADING TO THE GROUNDWATER = 11989.07 LBS/YR

ASSUMPTIONS:
1. OPEN SPACE, SOYBEANS AND WOODS WILL NOT BE FERTILIZED.
2. THE CULTIVATED LANDS WILL BE HALF SOYBEANS AND HALF CORN.
3. GROUNDWATER NITROGEN LOADING FOR FERTILIZATION FROM CULTIVATED LANDS = 30% OF APPLIED NITROGEN LOADING.
4. GROUNDWATER NITROGEN LOADING FOR FERTILIZATION FROM RESIDENTIAL LAWNS = 15% OF APPLIED NITROGEN LOADING.
5. GRASSED AREA ASSUMED NOT TO BE FERTILIZED CONSISTING OF OPEN SPACE, BUFFER ZONE, AND RIGHT-OF-WAY.

BACK CREEK
WATER RESOURCE MANAGEMENT
SUMMARY OF QUARTERLY GROUNDWATER ANALYSIS

MONITORING WELL #1
Table 1

Sample Date	pH	Alkalinity (mg/l)		Total Dissolved Solids (mg/l)	Nitrogen		Biochemical Oxygen Demand (mg/l)	Chemical Oxygen Demand (mg/l)	Chlorine Residual	Fecal Coliform (/100 ml)
		to pH 4.5	to pH 8.3		Nitrite Nitrogen (mg/l)	Nitrate Nitrogen (mg/l)				
Dec 1993	6.87	67.	<1.	210.	<0.02	13.	<2.	<50.	Negative	<10.
Mar 1994	6.90	47.	<1.	200.	<0.02	15.	<4.	<50.	Negative	<10.
Average (Mean)	6.89	57.	<1.	205.	<0.02	14.	<3.	<50.	-	<10.
Minimum	6.87	47.	<1.	200.	<0.02	13.	<2.	<50.	-	<10.
Maximum	6.90	67.	<1.	210.	<0.02	15.	<4.	<50.	-	<10.

NOTES:
1. mg/l = milligrams per liter
2. /100 ml = per 100 milliliters
3. This table is part of a report entitled "Water Resource Management Plan, Quarterly Groundwater Monitoring, April 1994 Reporting Period, Report No. 1," for Back Creek, Middletown, Delaware, and should be viewed only in the context of that report.

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April 1994

BACK CREEK
WATER RESOURCE MANAGEMENT
SUMMARY OF QUARTERLY GROUNDWATER ANALYSIS

MONITORING WELL #2
Table 2

Sample Date	pH	Alkalinity (mg/l)		Total Dissolved Solids (mg/l)	Nitrogen		Biochemical Oxygen Demand (mg/l)	Chemical Oxygen Demand (mg/l)	Chlorine Residual	Fecal Coliform (/100 ml)
		to pH 4.5	to pH 8.3		Nitrite Nitrogen (mg/l)	Nitrate Nitrogen (mg/l)				
Dec 1993	7.67	100.	<1.	230.	<0.02	10.	<2.	<50.	Negative	<10.
Mar 1994	6.80	58.	<1.	220.	<0.02	20.	<4.	<50.	Negative	<10.
Average (Mean)	7.24	79.	<1.	225.	<0.02	15.	<3.	<50.	-	<10.
Minimum	6.80	58.	<1.	220.	<0.02	10.	<2.	<50.	-	<10.
Maximum	7.67	100.	<1.	230.	<0.02	20.	<4.	<50.	-	<10.

NOTES:
1. mg/l = milligrams per liter
2. /100 ml = per 100 milliliters
3. This table is part of a report entitled "Water Resource Management Plan, Quarterly Groundwater Monitoring, April 1994 Reporting Period, Report No. 1," for Back Creek, Middletown, Delaware, and should be viewed only in the context of that report.

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